2019

# Reliability and Market Considerations For

# A Grid In Transition

A Report from the New York Independent System Operator

December 20, 2019

# Table of Contents

# Executive Summary

## Introduction

In a time of unprecedented change in the electricity sector, New York's competitive electricity markets are positioned to unleash the innovation and flexible energy solutions necessary for a reliable transformation towards a zero-emissions power grid. A rapid transition is underway in New York State from a power grid where energy is largely produced by central-station fossil fuel generation, towards a grid with increased renewable intermittent resources and distributed generation.

The pace of this transition is driven primarily by state policy, notably New York's Climate Leadership and Community Protection Act (CLCPA). In addition, technological advancements are expanding the capabilities of new resources and lowering their costs, further driving broader industry changes. In order to achieve the transformation anticipated, the NYISO, together with stakeholders, must provide the leadership to develop innovative products that allow wholesale markets, including energy, ancillary services and capacity, to serve the reliability requirements of New Yorkers while maximizing efficiency through this transition.

The central question arising for the NYISO is how the wholesale markets in New York can continue to provide the pricing and investment signals necessary to reflect system needs and to incent resources capable of resolving those needs. The key is to anticipate the needs for existing and new grid reliability services and proactively evolve the wholesale market design to balance the electric system to achieve reliability. To maximize the benefits of the new types of resources expected, the NYISO will leverage its expertise in developing and operating best-in-class wholesale markets, to enhance its market structure to facilitate the reliable transition towards a renewable resource base.

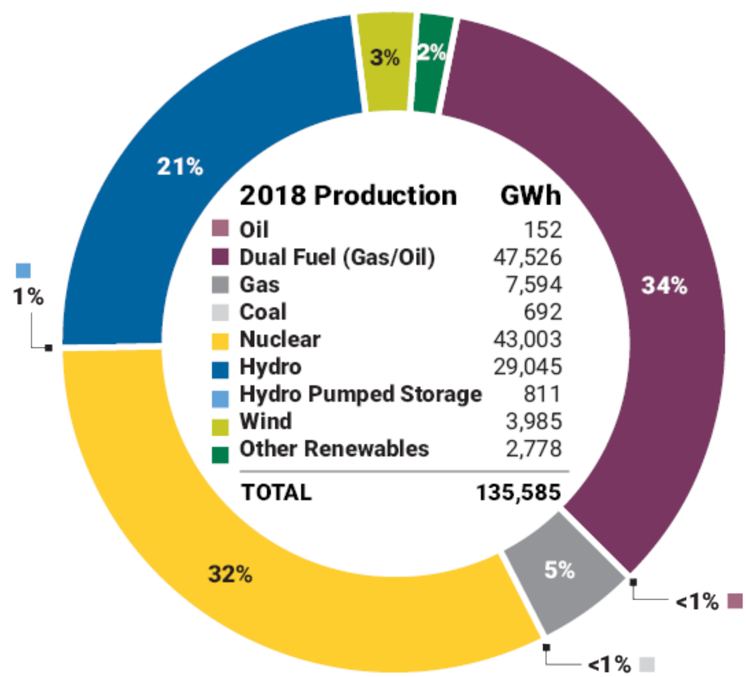
The NYISO is actively working on market enhancements to meet these future challenges. A grid characterized by high levels of intermittent renewable resources and distributed generation will require new thinking. We approach this work with two guiding principles: (1) all aspects of grid reliability must be maintained; and (2) competitive markets should continue to maximize economic efficiency and minimize the cost of maintaining reliability while supporting the achievement of New York's climate policy codified in the CLCPA.

This white paper is intended to facilitate a thorough review of a recommended set of market enhancements to ensure that the market signals provided through the energy, ancillary services and capacity markets are aligned with system reliability needs in order to attract investment and retain competitive suppliers through the transition to 70% renewable energy by 2030. We need to take the necessary steps to prepare and further shape the competitive markets, and identify strategic transmission investment opportunities for the change that is underway and then continue to evolve our markets as a better understanding of the long term challenges is developed.

In order to further that objective this whitepaper: 1) describes the emerging reliability and economic challenges; 2) presents our initial identification of gaps to address; and 3) proposes next steps. We focus on market design improvements, but also identify the required operations and planning studies that will inform the trajectory of how to meet reliability as we transition to a carbon free future.

### Public Policies and Clean Energy Technologies Are Reshaping the Grid

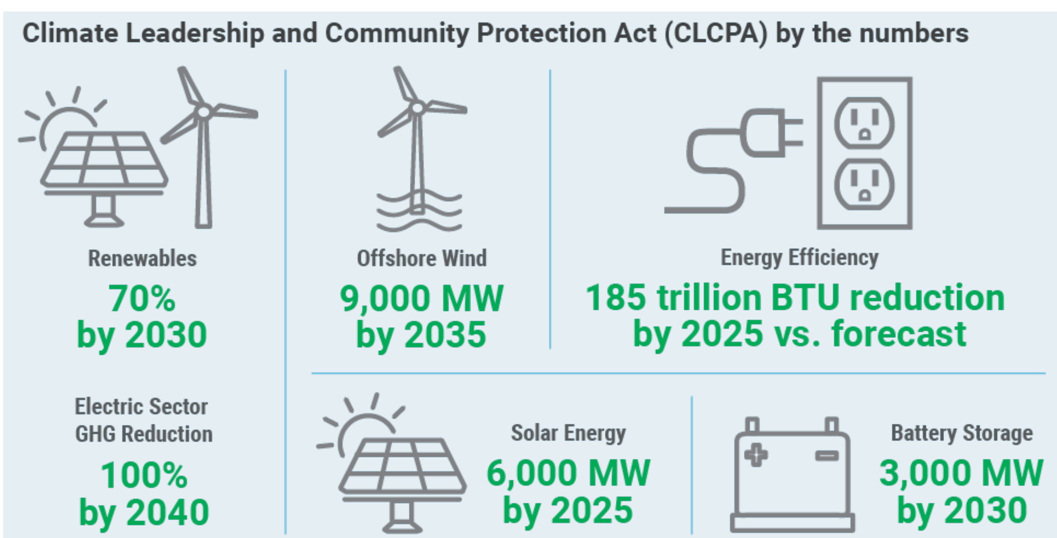
New York's electricity industry is transforming from a grid that is powered by traditional central-station, controllable fossil fuel generation to non-emitting, weather-dependent intermittent resources and distributed generation. Since their inception, NYISO's markets have a proven history of evolving to facilitate the integration of new technologies while continuing to meet reliability requirements in an economically efficient manner. These markets can be leveraged to support the transition to the grid envisioned by the CLCPA, including the integration of storage and renewable technologies. It is important to consider the current sources of energy within New York relative to the mandates established by the CLCPA in order to frame the magnitude of the change that must be achieved. In 2018, 27% of the energy production within New York was derived from renewable resources like hydro, wind and centralized solar, 32% from nuclear and 41% was provided by fossil based resources. For context, in 2018 New York's bulk power system operated only 1,985 MW of land-based wind, 32 MW of utility-scale solar (much of the solar installed to date is located behind-the-meter).



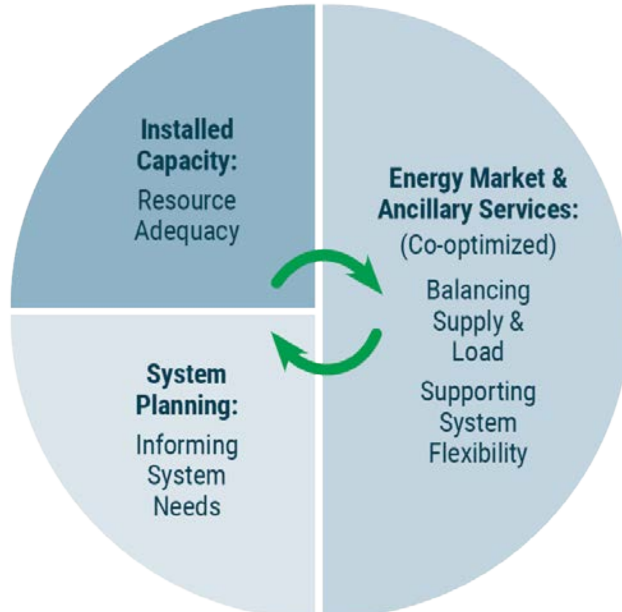

The CLCPA establishes that 70% of load will be served by energy generated from renewables by 2030 while requiring that 100% of the energy serving load be zero emission by 2040. The legislation specifies deployment of 9,000 MW of offshore wind, 6,000 MW of solar, and 3,000 MW of energy storage. A significant transformation in the mix of system resources is needed to reach these goals and markets can help.

Additionally, New York's economy-wide Greenhouse Gas (GHG) emissions goals and clean energy mandates stand out as having clear and substantial impacts on the NYISO wholesale markets and will be the major driver for the individual policies that can affect the NYISO wholesale markets going forward. GHG emission reductions will likely require even more changes including substantial electrification for heating, transportation, heavy industry, and other direct uses of fossil fuels that contribute to in-state greenhouse gas emissions. The NYISO recently developed enhanced load modelling techniques to incorporate future impact on load forecasts driven by climate change policies.

Wholesale markets are designed to attract and retain enough resources in the right locations to provide the needed reliability attributes; in the simplest terms to balance the supply and demand on the electric system. Within today's system there is a predominance of large-scale controllable resources that can be dispatched by operators to respond to system needs. In the grid of the future, where more intermittent resources are expected to interconnect to the grid, markets must incent sufficient resources to meet consumer demand, and also must attract controllable resources that will be necessary to balance varying supply from wind and solar. Furthermore, it is necessary to consider how markets can more explicitly recognize environmental attributes. Properly enhancing market designs to reflect this paradigm shift in how the grid is to be operated will ensure consumers continue to benefit from competitive markets that deliver economically efficient energy supplies to reliably serve demand while also supporting achievement of policy goals.



### NYISO Markets Provide a Framework for Integrating New Technologies and Achieving Policy Objectives

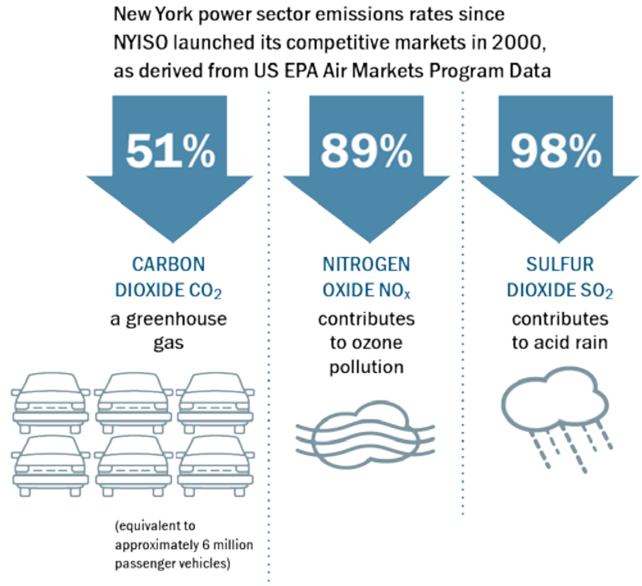



Wholesale markets harness competitive forces to improve the economic efficiency of operations and investment and encourage innovation. Asset owners who are most efficient will thrive in the market while lowering the costs of providing resources to consumers; those asset owners who have inefficient resources or make poor investment decisions bear the consequences and exit the market without placing additional cost burden on consumers.

The NYISO supports reliability primarily through three complementary markets for energy, ancillary services, and capacity. Each addresses distinct reliability needs, and each provides competitive market pricing designed to meet reliability needs at an overall least-cost to consumers. NYISO's markets are designed to provide pricing on a locational level in order to reflect the reliability needs of specific areas of the state. This locational pricing model minimizes overall costs to the state while serving as an important investment signal for investors.

Together, energy, ancillary services, and capacity revenues, provide economic signals for new investment, retirement decisions, and participation by demand response providers. When the energy and ancillary services components decrease, the capacity market prices increase to allow for sufficient revenues for needed resources (new or existing). Thus, our current market design is structured to allow resources to compete to provide reliability services while maintaining revenue adequacy for needed resources (i.e., retain resources that are providing reliability value and incent entry of new resources to maintain specified reliability levels – Loss of Load Expectation of 1 event in 10 years). While the capacity market is designed to meet resource adequacy, the energy and ancillary services markets provide the primary incentive for units to perform in real time and respond to rapidly changing system conditions. Well-functioning markets create opportunities for all resources, new and existing, to compete.

Competitive markets provide a framework for change in the power system. By way of example, it is helpful to note that the wholesale markets have played a significant part in meeting New York's environmental goals since the inception of the NYISO. Since 1999, New York's generation fleet has evolved to become markedly cleaner and more efficient. 11,335 MW of new generation has been developed in optimal locations due to locational energy and capacity price signals. Competitive market pricing has contributed to 7,343 MW of older facilities retiring or suspending operations and being replaced by cleaner fuel types and more efficient technologies. More recently, the NYISO developed comprehensive market rules for the integration of Energy Storage and Distributed Energy Resources (DER) into the wholesale markets. Currently pending FERC approval, the NYISO's proposed implementation of these market frameworks will provide increased opportunities for renewables and storage.




There is clearly more to do, but the NYISO's existing market structure is readily adaptable to changing system needs and public policy priorities. Going forward, the competitive market framework will serve as a platform to facilitate expanded policy goals and integrate advanced clean energy resources.

### How to Evolve the Markets to Meet Changing Needs

The NYISO's wholesale markets can continue to successfully fulfill the mission and goals of reliability and economic efficiency while also serving as an effective platform for achieving New York State environmental objectives. As such, the NYISO is actively engaging stakeholders and policymakers in developing plans to meet the future challenges expected to arise from a grid characterized with high levels of energy supply from intermittent renewable and DER.

We have identified several recommended market design enhancements. While each of these efforts addresses the concerns and follows the principles outlined above, they must fit together coherently and efficiently satisfy New York's grid reliability needs. As technologies change and the asset mix evolves, continued assessment and on-going market improvements will need to occur.

The energy and ancillary services design enhancements will provide appropriate pricing signals for generating resources that are responsive to real time changes in system conditions. Quick start capability, ramping and load following are needed for a system comprised of a large percentage of intermittent resources. An approach that emphasizes energy and ancillary services products and market pricing that are reflective of system conditions and operational requirements is important for incenting those needed attributes.

The NYISO continues to see the implementation of carbon pricing as the most effective means to directly reflect the public policy goals with respect to evolving to a zero carbon future into the markets. Shortage pricing for energy and ancillary services is particularly important to provide incentives for generating units to respond to real-time needs and to signal investment. There is a need to create more granular operating reserve areas to provide targeted price signals by location for ancillary services (e.g., within New York City to provide more accurate price signals for units to carry reserves).

As highlighted by the New York Public Service Commission (PSC) in the Resource Adequacy proceeding, steps also need to be taken to enhance the capacity market. It is important to improve the resource adequacy models used to set the Installed Reserve Margin and Locational Capacity Requirements and better align compensation with performance given the changing power grid.

Notably, the NYISO's existing capacity market Buyer Side Mitigation (BSM) rules require review in order to preserve competitive price signals and economically efficient market outcomes required to maintain system reliability and support the achievement of New York's climate policy codified in the CLCPA. To achieve this, the NYISO plans to engage with stakeholders to conduct a comprehensive review of the BSM rules aimed at modifying NYISO market structures in a balanced manner that support the transitioning grid.

This transformational shift in resources and potential for significant electrification of heating, transportation, and heavy industry necessitates addressing the impacts on the NYISO market design today. The projects presented below require immediate attention and are recommended for implementation in the next five years, through 2024.

**Table 1: Recommended Enhancements Requiring Immediate Attention**

| Market Enhancement Opportunity | Description |
|---|---|
| **Energy & Ancillary Service Market Opportunities** | |
| Carbon Pricing | Internalize the societal cost of carbon dioxide emissions via a $/ton charge to participants in the energy and ancillary services markets. Implementation requires state support. |

| Market Enhancement Opportunity | Description |
| --- | --- |
| Enhance Energy and Shortage Pricing | Enhance energy and shortage pricing such that prices are consistent with customers' value of lost load and probability of outage as supply conditions tighten and with smoother demand curves. Ongoing efforts include:<br>▪ Ancillary Services Shortage Pricing<br>▪ Constraint Specific Transmission Shortage Pricing<br>▪ Enhanced Fast Start Pricing |
| Review Energy and Ancillary Services (E&AS) Product Design | Further analysis to evaluate whether today's ancillary services products will continue to support reliable operations and investment signals as the system evolves. Ongoing efforts include:<br>▪ More Granular Operating Reserves<br>▪ Reserve Enhancements for Constrained Areas<br>▪ Reserves for Resource Flexibility |
| Distributed Energy Resources | In 2019, NYISO worked with its stakeholders to develop a comprehensive set of rules to integrate Distributed Energy Resources into wholesale markets. These rules are awaiting FERC approval and scheduled to go into effect in 2021. |
| Energy Storage Resources | In 2018, the NYISO developed market rules for integration of Energy Storage in wholesale markets. These rules are awaiting FERC approval and are scheduled to be implemented in 2020. |

| **Capacity Market Opportunities** | |
| --- | --- |
| Comprehensive Mitigation Review | A holistic evaluation of the BSM rules and methodology to evaluate how to modify NYISO market structures in a balanced manner that preserves competitive price signals and economically efficient market outcomes required to maintain system reliability and supports the Climate Leadership and Community Protection Act (CLCPA) goals. |
| Enhancements to Resource Adequacy Models | Evaluate the robustness of NYISO's resource adequacy models and make updates as needed to reflect emerging technologies and changing system dynamics.<br>▪ Modeling of storage and other duration limited resources<br>▪ Modeling of intermittent renewable resources<br>▪ Modeling of demand response<br>▪ Modeling of the dynamic and variable behavior of behind-the-meter solar and load modifiers |

| | |
|---|---|
| Revise Resource Capacity Ratings to Reflect Reliability Contribution | Develop enhanced capacity ratings for all supply resources that reflect the marginal contribution to meeting resource adequacy criterion, accounting for system dynamics, resource availability and performance (including the impact of outage correlations). Ongoing efforts include:<br>▪ Expanding Capacity Eligibility<br>▪ Tailored Availability Metric<br>▪ Recurring study building upon the above initiatives |
| Capacity Demand Curve Adjustments | Incremental adjustments to the capacity demand curve, including the shape and slope, to ensure resource adequacy and price stability as system conditions evolve. |

It is the NYISO's belief that twenty years of wholesale markets in New York have provided substantial benefits to New Yorkers. Leveraging this success, engagement with policymakers and stakeholders to address the challenges and potential solutions identified in this report will play an important role in achieving the environmental objectives of the state while maximizing the benefits of wholesale markets to New York's energy consumers.

# Background

## The Value of Markets

New York's electricity system is undergoing a major change, driven primarily by a wide array of state policies that affect the electric power system. Prior to the inception of NYISO wholesale markets in 1999, New York had a vertically integrated utility model. Economic efficiency concerns, as well as an investment model that placed the burden of investment risk on ratepayers, led to the creation of the wholesale markets administered by the NYISO. The main drivers behind wholesale markets was the desire to inject economic efficiency and price transparency into grid operations, and to shift the risk and cost consequences related to poor investment decisions in the cost-of-service regulated regime from consumers to investors.

Wholesale energy markets also support retail competition, whereby competitive retailers buy supplies from the wholesale energy market on behalf of their customers, obviating the need for regulated integrated resource planning to satisfy retail customer demand. This also shifts risk from consumers to competitive retailers in much the same way risk shifted from consumers to generation owners in the wholesale energy market.

Wholesale energy markets harness competitive forces to improve the economic efficiency of operations and investment and encourage innovation while shifting risk to those parties that own the resources and are best able to mitigate that risk. Owners of the most efficient generation assets thrive in the market, which results in lower costs for consumers. Asset owners who make poor decisions leading to high costs bear the consequences of those decisions and exit the market without placing any additional cost burden on consumers.

Competitive wholesale markets include energy, ancillary services and capacity markets. The energy and ancillary services markets guide least-cost dispatch and maintain operational reliability. The capacity market works in tandem with the energy and ancillary services markets to achieve longer-term resource adequacy objectives in the most cost-effective manner. Together these markets provide the revenue necessary to retain and attract sufficient investment to meet reliability criteria with the most efficient set of resources, with diverse operational characteristics. Having resources with diverse operational characteristics makes it more likely that there will be resources available that can respond to unexpected system needs.

The NYISO wholesale markets have thus far met their objective of maintaining reliable service at the lowest possible cost. Since 2000, the NYISO's markets have attracted competitive new entry, the risk of which is borne by the investors and owners of new generation, to replace more than 7,000 MW of retirements while maintaining high operational reliability with limited out-of-market interventions.[1] The NYISO's markets have consistently been competitive, according to its external Market Monitoring Unit (MMU). They have attracted new investment below administrative estimates of the cost of new entry, reflecting the market's ability to provide innovative and low-cost solutions, such as efficiency improvements in existing resources, including unit uprates, and advanced technologies like flywheels and batteries and demand response.[2]

### Policies Transforming the New York Power System

Policy objectives have now evolved beyond the reduction of criteria pollutant emissions such as sulfur dioxide, nitrogen oxides, and particulates to include promoting renewable energy, and accounting for environmental externalities related to carbon dioxide emissions, among other goals.[3] The impact of each policy on the wholesale markets varies greatly. Some policies are highly compatible with the current market design, while others impose operational and reliability challenges that require larger market reforms.

**Table 2: Selected Major New York Policy Drivers in addition to the Climate Leadership and Community Protection Act**

| Policy Initiative | Policy Goal | Potential Wholesale Energy Market Challenge |
|---|---|---|
| **State Policies Directly Impacting Fossil Generation** | | |
| Clean Energy Standard Zero Emission Credits (ZEC) | Retain upstate nuclear units through 2029 | |
| Regional Greenhouse Gas Initiative (RGGI) | Reduce carbon dioxide emissions cap by 30% from 2020 to 2030 and expand applicability to currently exempt "peaking units" below current 25 MW threshold | None. These costs are already reflected in the wholesale markets. |
| NYC Part 251 $CO_2$ Limits | Establish restrictions on carbon dioxide emissions for fossil fuel-fired facilities in New York by 2020. | Deactivation of remaining 860 MW of coal; reduced fuel diversity |

1 See NYISO (2019f) and Potomac Economics (2016) through Potomac Economics (2019).

2 See Potomac Economics (2016), (2017), and (2018). In 2017, MMU found energy market performed competitively and capacity market was sound, but provided 21 recommendations for enhancement to the market design. The MMU reached similar conclusions in the 2016 and 2015 State of the Market reports.

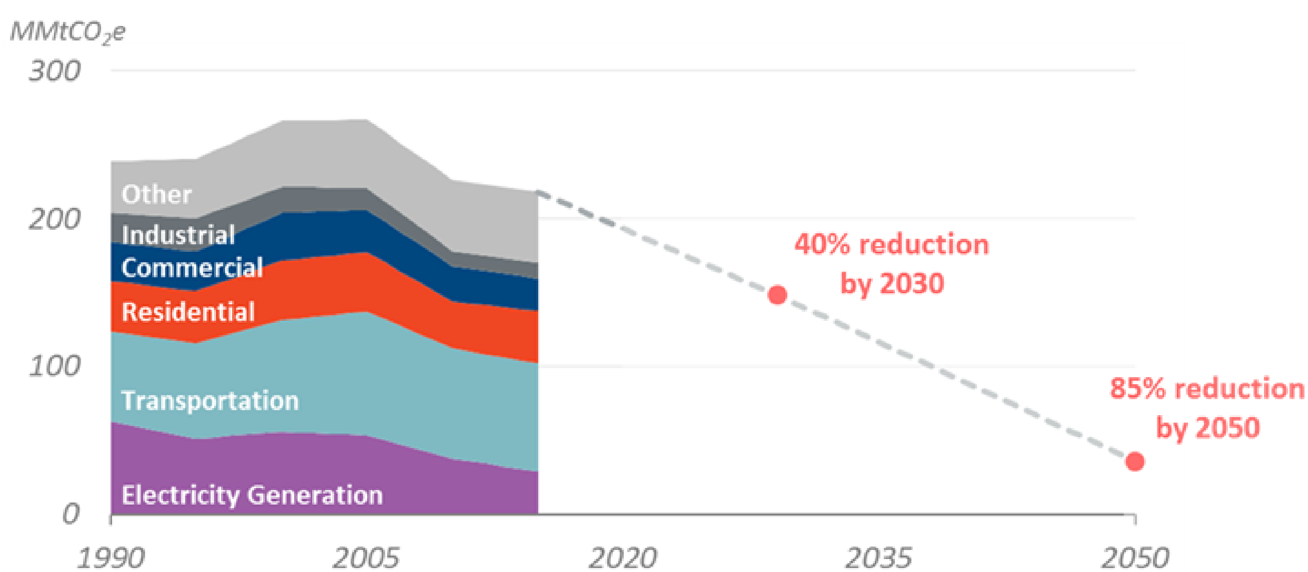
3 Criteria pollutants include emissions of sulfur dioxide, nitrogen oxides, and particulates

| Policy Initiative | Policy Goal | Potential Wholesale Energy Market Challenge |
|---|---|---|
| NOx Rule Proposed | Reduce ozone-contributing pollutants associated with New York State-based peaking unit generation. | Energy market pricing and capacity market structure do not fully capture granular operating needs and fast response provided by peaking generation.<br><br>The NYISO in developing its Comprehensive Reliability Plan (CRP) for 2019-2028 includes a study scenario evaluating the potential reliability impacts of the deactivation of 3,300 MW of peaking generators affected by the proposal. |
| New York City Residual Fuel Oil Elimination | Eliminate combustion of fuel oil numbers 6 and 4 in NYC by 2020 and 2025, respectively | Nearly 3,000 MW of New York City generation with oil capability may be affected, requiring a transition to number 2 fuel oil and possibly leading to reduced fuel diversity. |
| **State Support for Non-Traditional Resources** | | |
| Value of Distributed Energy Resources (VDER) | Transition from Net Metering (NEM) to VDER value stack compensation for DERs on the distribution system | Coordination between real-time wholesale energy market signals and retail mechanisms to encourage an efficient mix of DERs |
| **Federal Policies** | | |
| MOPR/CASPR Buyer-Side Mitigation | RTOs may bar resources from offering into capacity auctions below going-forward costs, but may exempt state-sponsored resources | Integrating resources receiving out of market payments, such as REC, ZEC and contracts for energy storage, into capacity auction |
| Energy Storage Order | Require RTO tariff revisions to facilitate participation of energy storage in wholesale markets | Optimally dispatching storage under greater supply and demand uncertainty and evaluating storage's resource adequacy value |
| DER NOPR | Require RTO tariff revisions to facilitate participation of aggregate DER | Optimally scheduling aggregated DERs under greater supply and demand uncertainty |
| Grid Resilience | Maintain and enhance grid resilience by retaining fuel secure, baseload generation | FERC and DOE initiatives under consideration could result in cost-of-service compensation mechanisms to be put into place which would be designed to maintain operations of targeted baseload resources. |

Any market enhancements must take into consideration a variety of policy drivers and their consequences for the wholesale energy market. Central to these is the recently enacted CLCPA which requires 70% of state's electricity needs be served by renewable generation resources by 2030, 100% "zero emissions" power grid by 2040 along with energy efficiency and technology specific goals including an offshore wind target of 9,000 MW by 2035, 6,000 MW distributed solar by 2025, 3,000 MW storage by 2030, and 185 trillion BTU energy reduction due to energy efficiency by 2025. [4] Table 2 summarizes other key Federal, state, and New York City electricity policies, their objectives, and their potential implications for the NYISO wholesale energy market.

New York's economy-wide Greenhouse Gas (GHG) emissions goals and clean energy mandates stand out as having clear and substantial impacts on the NYISO wholesale markets and will be the major driver for the individual policies that can affect the NYISO wholesale markets going forward. Figure 1 below illustrates New York State historical greenhouse gas emissions and a linear trajectory to meet the targeted reductions. GHG emission reductions will likely require even more changes including substantial electrification for heating, transportation, heavy industry, and other direct uses of fossil fuels that contribute to in-state greenhouse gas emissions. This transformational shift and potential electrification necessitates addressing the impacts on the NYISO market design today.

**Figure 1: New York State Economy-Wide GHG Emissions History and Future Reduction Goals**



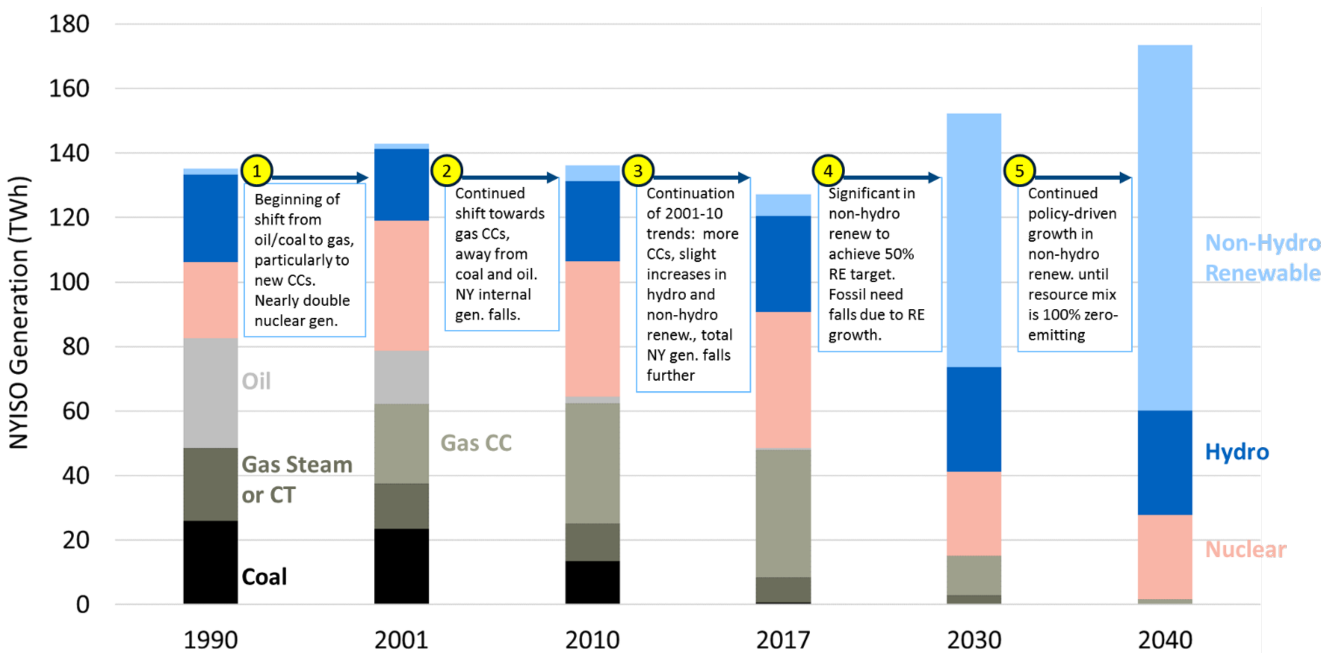

Sources and Notes: New York State Energy Research and Development Authority (2018), analysis performed for NYISO by Brattle. MMtCO2e is million metric tons of carbon dioxide equivalent. CLCPA goals are relative to 1990.

4 See New York State Senate (2019)

Figure 2 illustrates how the New York supply mix has changed since 1990 and may continue to evolve into the future. In 1990, fossil fuel-fired generation dominated the generation fleet. However, public policy drove changes between 1990 and 2001. Compliance with the 1990 Clean Air Act Amendments began in 1995 with the Sulfur Dioxide Trading Program and programs to reduce nitrogen oxide emissions. The NYISO markets started trading in 1999. In combination these changes significantly altered the generation mix in just over a decade.

By 2001, the dominance of high-emitting coal and oil in the generation fleet had waned, and natural gas-fired combined-cycle generation and improved nuclear performance had come to the fore. Competitive market incentives (in both the wholesale markets and the emissions markets) had driven a large change in New York's generation fleet making it more efficient, lower cost, and lower emitting. Demand fell due to energy efficiency and the recession of 2008–2009. By 2010, the state was also experiencing an uptick in renewable resources, resulting largely from New York's Renewable Portfolio Standard (RPS) and procurements to meet the RPS.

**Figure 2: Change in New York Supply, 1990 - 2040**




Sources and Notes: 2001, 2010 and 2017 data from S&P Global Market Intelligence (2019). 2030 and 2040 data is from GridSIM modeling results, conducted by The Brattle Group.

The trends observed from 2010 to 2017 include continued decreases in the rate of growth of demand, additional environmental policies, such as the Mercury and Air Toxics Standards (MATS), and dramatic reductions in the cost of natural gas with the advent of shale gas from the Marcellus production region. Gas-fired combined-cycle technology improvements and increased energy efficiency continued. These trends have eroded the economics of coal and oil-fired generation in New York.

The takeaway from Figure 2 is the role of markets in achieving this transition. From 1990 to today New York faced large-scale changes, emissions markets and wholesale markets, working together with policy, achieved a fuel and technology mix transition that was unimaginable in 1990. Looking forward from 2019 to 2040, renewable procurements and long-term decarbonization will drive larger growth in non-hydroelectric renewable resources. The retirement of Indian Point and potentially other nuclear facilities will cause a decline in nuclear generation shown by 2030.

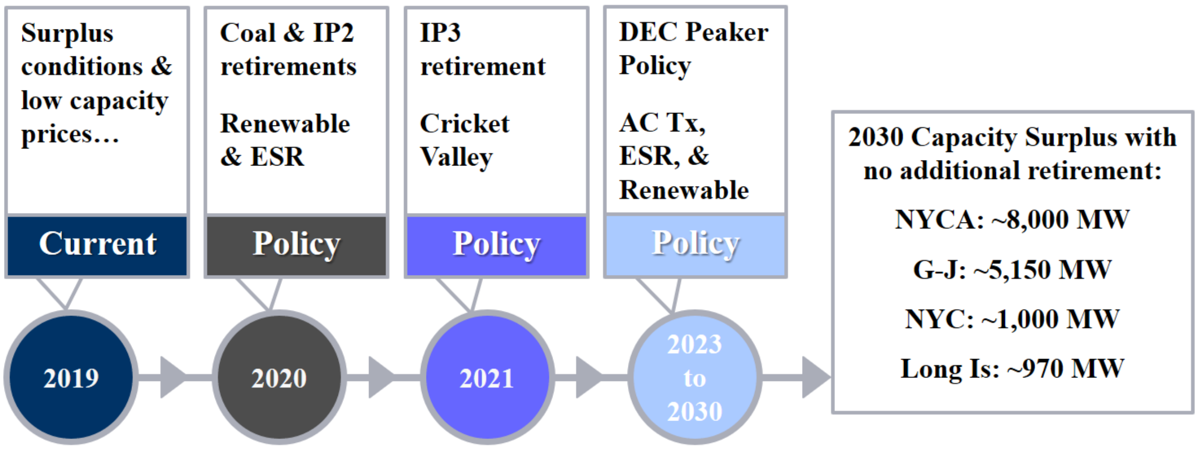
The markets have not picked winners and losers in advance; but instead wholesale markets and emissions markets allowed the lowest cost and most innovative technologies and processes to flourish. Wholesale energy markets in conjunction with emissions markets are expected to continue to provide similar results in the future even though we may not yet know how the system will actually evolve. The NYISO is preparing its wholesale markets to continue to support grid reliability as the New York power system transitions to a decarbonized future.

### New Challenges in a Decarbonizing System

Nationwide, companies are continuing to build stronger, smarter energy infrastructure to provide consumers a more reliable and resilient grid. These efforts seek to increase access to new supply resources and technologies that promote economic competition and environmental stewardship. Without market-based incentives for investment in renewable resources and absent a more robust transmission system to move power to load, state policies could promote a resource mix where new renewable resources increasingly displace the output from existing renewable or other zero-emitting resources. Absent additional transmission, curtailments will only grow as new wind and solar resources connect to the upstate grid. To facilitate investment in new and upgraded transmission, the NYISO's planning processes provide independent and authoritative information to investors, stakeholders, and policymakers. In response to reliability needs identified by the NYISO and public policy needs identified by the New York State Public Service Commission, the NYISO has the ability to call for market-based and regulated solutions to meet these needs and select the more efficient or cost effective transmission solution. These planning processes support the reliability and efficiency of the electric grid and the ability of the electric grid to support public policy goals.

**Figure 3: How Policies Stack Against Present Conditions**

| 2018/19 Conditions | NYCA | G-J Locality | New York City | Long Island |
|---|---|---|---|---|
| Surplus Capacity | 2,738 MW | 959 MW | 967 MW | 523 MW |
| Capacity Price (as % of Net CONE) | 24% | 47% | 38% | 34% |

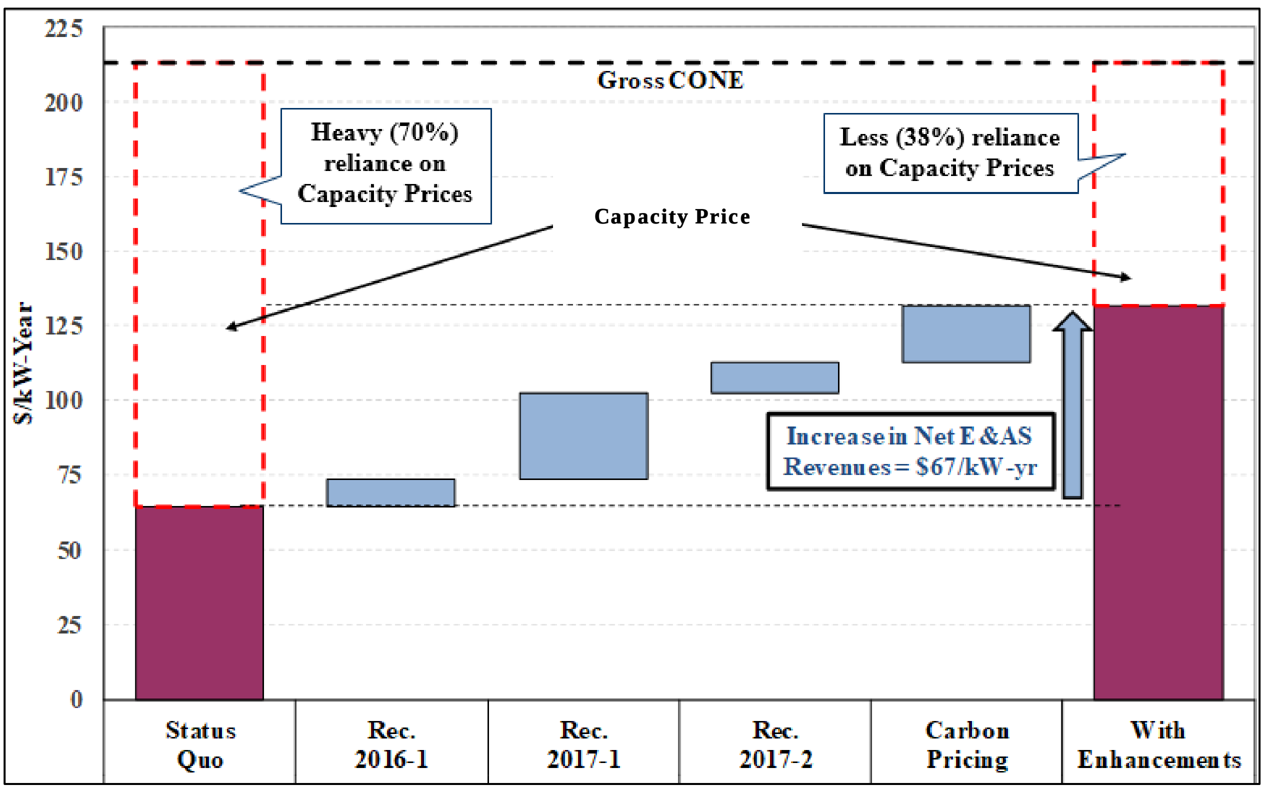



Source: Based on Potomac Economics (2019b), slide 9.

Moreover, the monumental shift in the generation mix portrayed above in Figure 2 along with the potential incremental increased demand from electrification, poses a multitude of challenges to the NYISO's primary goal of supporting a reliable and economically efficient electric grid. These new renewable resources have economic and performance characteristics that differ from the current NYCA resources. These performance characteristics may also not align well with the requirements of the current wholesale energy market design. Additionally, as indicated in Figure 3 above from NYISO's MMU, there may be a need for retirement of inflexible generation to support new intermittent renewable resources and various policies. Many of the new resources will be weather-dependent (*e.g.*, wind and solar resources), which creates new operational challenges and may require large amounts of flexible, controllable resources to maintain a reliable system. These renewable resources also have zero or very low variable costs, which reduces energy prices, on average and in most hours. This reduction in energy market revenue due to lower energy prices places greater emphasis on expanding ancillary services revenues to retain flexible, controllable resources to maintain reliable system operation. Absent a corresponding increase in ancillary services revenues or other wholesale energy market changes to bolster energy prices, investment signals for flexible, controllable resources may be insufficient to meet future reliability challenges.

The wholesale energy market design will have to evolve to fully value grid services needed to maintain reliability as the generation fleet changes. Figure 4 is an example of this provided by the NYISO's MMU. Ideally, the wholesale energy market will signal the value of each type of grid service needed and recognize the value of environmental objectives (either by internalizing into the wholesale markets, or through parallel competitive processes for environmental attribute markets). Then the wholesale energy market can meet the full spectrum of state objectives and needed grid services, with competitive forces guiding the least-cost solution from a diverse set of resources, each with its own characteristics. The wholesale energy market's ability to meet multiple objectives at least-cost is especially important now, given the state's ambitions to transform the electric grid.

**Figure 4: Enhancing Incentives for Key Attributes**




Source and Notes: Derived from Potomac Economics (2019b), slide 11.
Rec. 2016-1: Compensate reserves that increase NYC import capability.
Rec. 2017-1: Create NYC load pocket reserves.
Rec. 2017-2: Increase Operating Reserves Demand Curve pricing levels.

Today's wholesale energy market design is up to this task including proactive enhancements to the market that recognize state objectives and the marginal value of the various, necessary grid reliability services. Several of these value-shifts will occur naturally under the current design as existing products become more or less valuable. However, this is a critical time to re-evaluate the completeness of the product suite and the adaptability of each product to changing conditions. The NYISO is proactively anticipating reliability needs and designing market solutions aligned with those needs well in advance of any actual issues that jeopardize reliability. Waiting to design and implement market enhancements until they are needed to support reliability is inefficient, could challenge reliability, and would also miss the opportunity to create appropriate and timely investments signals.

## Reliability Considerations

### Reliability Gap Assessment

New York's decarbonization policies are creating new challenges to meet NYISO's mission to support a reliable and economically efficient New York electric system. These challenges cross many of NYISO's responsibilities with respect to operations and planning. The NYISO has prepared a comprehensive report which is included in Appendix B. This section provides a high level overview of the findings of the report.

The potential areas of future reliability gaps assuming a high level of Intermittent and/or limited energy supply resources are expected to include:

1. Maintain Ability to Balance Load and Generation
2. Maintain Ten-Minute Operating Reserves
3. Maintain Total Thirty-Minute Operating Reserves
4. Maintain Ability to Meet Daily Energy Requirements
5. Maintain Reliable Transmission Operations
6. Maintain Black start Capability
7. Maintain Voltage Support Capability
8. Maintain Frequency Response Capability
9. Maintain Resource Adequacy
10. Ability to Manage Supply Resource Outage Schedules

### 1. Maintain Ability to Balance Load and Generation

Potential Reliability Gap # 1: The NYISO may be challenged to meet NERC control performance requirements balancing high levels of intermittent generation with system demand that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 1: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Increasing statewide regulation procurement requirements
b. Investigate benefits of separate regulation "up" and "down" service

c. Increasing statewide ten and/or thirty-minute operating reserve requirements
d. Investigating the need for ramping requirements in NYISO markets
e. Improving the NYISO's Real-Time Energy Market Dispatch
f. Accounting for increased real-time load forecast uncertainty
g. Promoting more frequent interchange scheduling with neighboring regions

Background:

It is generally recognized today that meeting New York load with high levels of intermittent resource output, particularly solar and wind generation, will require the NYISO to have sufficient flexible, dispatchable and potentially fast ramping supply to balance variations in intermittent resource output. These variations will include not only short-term variations in output during the operating day as a result of changes in wind speed and cloud cover but also a sustained ramp up of solar output at the beginning of the day as the sun rises and a sustained ramp down of solar output at the end of the day as the sun sets.

This potential reliability gap concerns the ability of the NYISO to balance load and generation within the time frame of the real-time dispatch and regulation markets with a resource and output mix that includes much more intermittent resource output than today. NERC tends to view this issue as simply a matter of the availability of resources able to provide load balancing. The challenges the California ISO has encountered in balancing load and generation show that the issues the NYISO will need to address as its resource mix changes will be more complex than this, involving not only the amount of flexible generation available to balance load and generation but also the ability of the balancing software, particularly RTD, to recognize the need to balance load and generation in the appropriate time frame and potentially changes in the way regulation instructions are determined by AGC.

The availability of sufficient ramp capability to balance variations in intermittent resource output will need to be addressed in five time frames. These are the time frame of the regulation balancing instruction, the time frame of the real-time dispatch, the time frame of the intra-day unit commitment decisions, the time frame of the day-ahead market, and the time frame in which investments in resources able to provide balancing will be made.

### 2. Maintain Ten-Minute Operating Reserves

Potential Reliability Gap # 2: The NYISO may be challenged to maintain ten-minute operating reserves and meet NERC disturbance control performance requirements in response to variations in the levels of intermittent generation.

NYISO Plan for Gap # 2: The NYISO will continue to track ten-minute operating reserves and applicable NERC Balancing Area Disturbance Control Standards and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Increasing statewide ten and/or thirty-minute reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

Background:

The scheduling of additional spinning reserves or ramp capability could play an important role in enabling the NYISO to balance load and generation as the New York resource mix evolves towards a substantially greater reliance on intermittent resource output. However, these increases in the level of intermittent resource output used to meet load on the NYISO transmission system also have the potential to impact the way the NYISO meets its spinning and total reserve targets that will need to be considered by the NYISO in parallel with these changes.

### 3. Maintain Total Thirty-Minute Operating Reserves

Potential Reliability Gap # 3: The NYISO may be challenged to meet NPCC Operating Reserve requirements to not be deficient in total balancing areas reserves for greater than four hours in response to longer term variations in the levels of intermittent generation.

NYISO Plan for Gap # 3: The NYISO will continue to track applicable NPCC Operating Reserve Standards performance and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Increasing statewide Total Operating (30-minute) Reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

Background:

The expected increases over the next 10 years in the level of zero or near zero incremental cost wind and solar output, both within the NYISO and in adjacent regions, potentially combined with output related regulatory and tax subsidies will likely cause energy prices to gradually fall, especially in the middle of the day. These low energy prices will make it more and more costly for the NYISO, and adjacent balancing areas, to keep resources on line at minimum load beyond those needed to provide required reserves and regulation Low energy prices within the NYISO and in adjacent balancing areas during the middle of the day when intermittent resource output is high has the potential to reduce the ability of the NYISO to restore contingency reserves following outages because there will likely be much lower levels of latent reserves available not only within New York but also lower levels of latent reserves on line in adjacent regions. This market tightness will be compounded to the extent that the NYISO uses energy-limited resources, particularly resources with very limited energy supply such as battery energy storage, to provide spinning reserves. Not only will the NYISO need resources that will enable it to restore 10-minute reserves following contingencies, the NYISO will also need to replace the energy output of energy limited resources whose reserves have been converted to energy that they will not be able to sustain beyond the required 1 hour minimum period.

### 4. Maintain Ability to Meet Daily Energy Requirements

Potential Reliability Gap # 4: The NYISO may be challenged to meet NERC control performance requirements managing high levels of intermittent limited energy storage supply resources to meet daily energy requirements in real-time operations.

NYISO Plan for Gap # 4: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and operating reserve criteria and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Developing new capability for operator management of limited energy supply resources
b. Increasing statewide ten and/or thirty-minute operating reserve
c. Account for real time load forecast and renewable uncertainty

#### Background:

If the NYISO becomes more dependent on the output of storage resources to balance variations in intermittent resource output and potentially relies on these resources to provide spinning reserves and regulation, the NYISO will need to be able to track the energy balance of these resources over the operating day. This information will enable the NYISO to assess the ability of these resources to provide reserves and to balance variations in intermittent resource output and take this capability into account in its dispatch, interchange scheduling and unit commitment decisions. As the role of storage or other energy limited resources expands, it will become increasingly necessary for the NYISO to develop systems for tracking the energy balance of energy limited resources participating in NYISO's energy and ancillary services markets so the NYISO's market and reliability processes do not count on resources being able providing services or supply that they will not be able to provide because of energy limitations.

### 5. Transmission Operations and Congestion Management

Potential Reliability Gap # 5: The NYISO may be challenged to meet NERC Transmission Operations requirements when operating under high levels of intermittent generation with system and locational demand requirements that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 5: The NYISO will continue to track applicable NERC, NPCC, and NYSRC Transmission Operations Standards and implement necessary operational and market changes in order to maintain acceptable performance. Such changes are detailed in the following section and in Appendix B and include:

a. Increasing transmission facility constraint reliability margins
b. Increasing locational ten-minute spin and total operating reserve requirements
c. Increasing locational thirty-minute total operating reserve requirements
d. Investigating the need for a locational (zonal) ramping product
e. Account for increased real time load forecast uncertainty
f. Monitor and manage sustainability

#### Background:

If the NYISO shifts to an operational pattern in which there are few thermal resources on-line during the peak intermittent resource output periods, the NYISO will need to ensure that it can continue to operate the transmission system in accordance with all applicable reliability requirements. As was the case when coal fired generation shutdown in western New York, the NYISO may find that new transmission constraints will bind that are difficult to manage given the lack of dispatch capability associated with intermittent resources. In addition, the implications of having reduced amounts of thermal generation on line and able to be dispatched up will need to be evaluated and addressed in the planning process as well as in the day-ahead market and real-time operations.

### 6. Restoration and Black Start Capability

Potential Reliability Gap # 6: The NYISO may be challenged to effectively restore the system within expected timeframes following a blackout given a system with high levels of intermittent generation.

NYISO Plan for Gap # 6: The NYISO will implement and monitor the effectiveness of established NERC and NYSRC Standards and procedures that require acceptable statewide and NYC restoration and black start capability performance are maintained as system changes occur through time. Such changes are detailed in the following section and in Appendix B and include:

a. Annual Review and Update of Restoration Plan
b. Coordination of NYISO and Transmission Owner Restoration Plans
c. Facilitate participation of resources in the Con Edison Restoration Plan

Background:

There are a number of reliability requirements established by the NYS Reliability Council (NYSRC) that require the NYISO to develop and maintain a NYCA System Restoration Plan (SRP) that provides assurance that the NYCA system will be restored in a safe and orderly manner and as promptly as reasonable possible following a major or total blackout. The NYSRC also requires that Each Transmission Owner shall establish and maintain a restoration plan that shall be coordinated with the restoration plans of other Transmission Owners and shall be part of the NYCA System Restoration Plan. Lastly, the NYSRC requires that the NYISO facilitate the participation of black start capable resources for the Con Edison Restoration Plan.

a. Annual Review and Update of Restoration Plan

Current NYSRC reliability rules already provide for an annual review and update of the NYISO system restoration plan. This review process would provide the framework for the NYISO to analyze the impact of changes in the NYCA resource mix on the system restoration plan and make necessary changes on an ongoing basis.

b. Coordination of NYISO and Transmission Owner Restoration Plans

Current NYSRC reliability rules already provide for coordination of NYISO and Transmission Owner Restoration plans. This coordination will continue to occur in the future and enable collective assessment of the impact of changes in the NYCA resource mix on the system restoration plan.

c. Facilitate participation of resources in the Con Edison Restoration Plan

The NYISO will continue to coordinate participation of resources in the Con Edison system restoration plan.

### 7. Voltage support

Potential Reliability Gap # 7: The NYISO may be challenged to meet NERC, NPCC, and NYSRC voltage performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 7: The NYISO will continue to study voltage performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Study voltage performance in long-term planning timeframe (RNA)
b. Study voltage performance in short-term planning timeframe (Operating Studies/Limits)
c. Investigate the potential for new resource types to supply reactive capability

Background:

The provision of voltage support will potentially be impacted in several ways by the prospective changes in the NYISO resource mix. First, with fewer thermal units on line and more output provided by asynchronous resources it may be necessary to at times rely on asynchronous resources to provide voltage support.

Second as energy prices fall during the peak solar hours and at times when wind generation output is high, it will become increasingly necessary to commit thermal resources specifically to provide voltage support, because few thermal resources will be committed based on economics during some periods of the day.

Third, low energy prices will make it very expensive to commit thermal generation at minimum load to provide voltage support, with the result that thermal resources committed to provide voltage support will incur large losses on their minimum load output.

### 8. Frequency Response

Potential Reliability Gap # 8: The NYISO may be challenged to meet NERC, NPCC, and NYSRC frequency performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 8: The NYISO will continue to study frequency performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and in Appendix B and include:

a. Study frequency performance in short-term planning timeframe (Operating Studies/Limits)
b. Investigate the potential for new resource types to supply frequency response capability

Background:

The NYISO's frequency response obligations will be determined by NERC, reflecting changes in the resource mix across the eastern interconnection. Various NERC studies indicate that frequency response will become more of a reliability issue as less thermal generation is on line. The NYISO will need to anticipate these requirements. Some of the performance factors that the NYISO will need to review are the potential need to commit generation to meet NERC requirements, rules limiting the circumstances in which plant level controls on synchronous generators can be set to override frequency response (and perhaps requiring notification of the NYISO when plants are operating in this mode), modeling the output range in which synchronous resources can provide governor response, introduce frequency response performance requirements, develop NYISO systems that model the amount of available frequency response and adjust dispatch and commitment to meet NERC targets.

### 9. Maintain Resource Adequacy

Potential Reliability Gap # 9: The NYISO may be challenged to maintain acceptable levels of resource adequacy.

NYISO Plan for Gap # 9: The NYISO will continue to monitor resource supply capability relative to targets (LOLE of 0.1 days per year) for the both the long-term planning and short-term operating timeframes and implement necessary operational and market changes. Such changes are detailed in the following section and in Appendix B.

#### Background:

Beyond the time frame of the operating day, the NYISO will need to ensure that there are appropriate financial incentives for investment in resources able to provide balancing services. These investment incentives could in principle be provided through capacity market or energy market incentives but there are a number of practical issues with both approaches that will need to be considered. First, assessment of reliability needs will become more complex as the level of thermal generation is reduced and replaced with the output of intermittent resources and storage. Second, the determination of capacity resource requirements, such as minimum output duration, will become more complex as the level of intermittent resource output and reliance on storage increases. Third, setting requirements for and incenting capacity resource performance will become more difficult as the need for flexible capacity increases. Each of these changes is discussed briefly below.

#### Reliability Needs

When intermittent resources participate in the capacity market, they result in an economic displacement in the capacity market of the need for traditional resources to the extent the intermittent resources are assigned capacity value. As increasing amounts of intermittent resources are added to the system, their incremental capacity value and hence their ability to displace other resources should be expected to decline due to the common operating characteristics of the resources. For example, large additions of solar resources may result in the shifting of the observed net peak load (load net of intermittent resource output) into evening hours when solar resources generate little or no output. Changes in the makeup of the resource fleet and the consumption patterns of electricity will require the NYISO to evaluate whether resource adequacy needs, and resource capacity values, continue to be defined by heat wave driven summer peak loads, or will need to shift to resource adequacy needs in alternative situations. The NYISO will need to continue to evaluate each resource’s contribution to reliability to ensure we are not overstating the incremental capacity value of particular types of resources, leading to an inaccurate displacement in the capacity market of resources that are needed to maintain reliability.

#### Resource requirements

The increasing importance of ramp capability and energy limits in reliably meeting NYISO load will impact many requirements for capacity resources used to balance net load, such as ramp rates, notification and start-up times, minimum load levels, minimum run times, number of starts per day, number of hours the resource can sustain output, seasonal and time of day availability. Setting these requirements will become more complex, not only because of the complexity of modeling how these characteristics impact the IRM and LCR, but also because the need for particular characteristics from incremental capacity resources depends on the aggregate characteristics of the capacity resources that will be used to meet the IRM.

### 10. Ability to Manage Supply Resource Outage Schedules

Potential Reliability Gap # 10: The NYISO may be challenged to manage supply resource maintenance outage scheduling.

NYISO Plan for Gap # 10: The NYISO will continue to monitor its procedures for supply resource outage schedule to determine whether additional operational and/or market changes should be implemented to help maintain operating capability targets throughout the year.

#### Background:

The NYISO will continue to play a role in coordination generation and transmission outages and will develop load and reliability forecasts that will assist generation and transmission owners in scheduling both long and short-term outages in periods in which they are less likely to adversely impact reliability.

Increases in intermittent resource output may lead to changes in the seasonal pattern of net load variations, making it more difficult for generation owners and the NYISO to schedule generation maintenance at times when the capacity is unlikely to be needed.

## Planning Challenges with the Growing Reliance on Intermittent Generation

Environmentally focused public policies are shaping the way energy is supplied and consumed in New York. Those policies have a significant impact on current transmission system conditions and future transmission needs. NYISO studies indicate that achieving public policy objectives will require additional transmission capacity in New York State to deliver renewable resources from constrained generation pockets to the bulk electric grid for delivery to consumers.

Much of New York’s existing and proposed renewable energy capability is upstate. The resource mix and geographic distribution of new renewable resources are expected to dramatically change power flows.

To maximize the load served by renewable generation, cross-state energy transfers will increase due to the fact that more renewable generation is available upstate to serve the downstate load.

As renewable energy production in the upstate regions exceeds the load in those same regions, additional energy transfers across the bulk electric grid from renewable resources to load centers statewide are necessary.

- Failure to expand transmission capabilities across the state could induce market inefficiencies, including increased curtailment of renewable generation and additional generator deactivation notices from units needed for reliability.
- Further, if markets are unable to produce appropriate price signals due to the expansion of renewable capacity without an adequate expansion of transmission capability, the state's goal of achieving 70% of end-use-energy generated by renewable energy systems by 2030 will be at risk because energy delivery from renewable resources to load centers will be constrained.

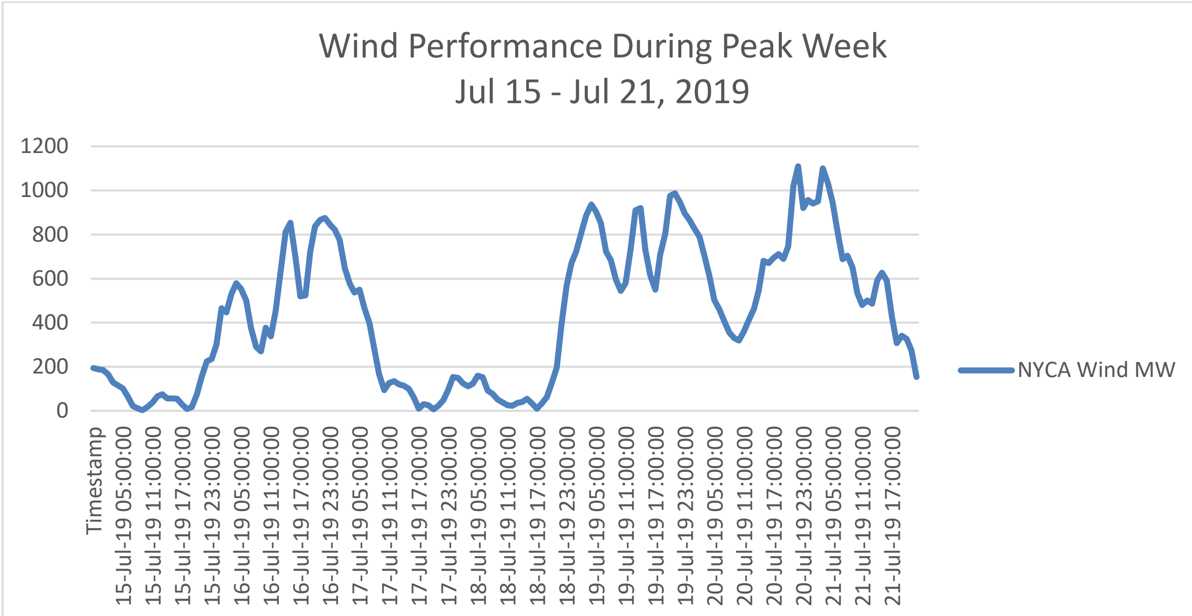
### The Challenge of Energy Usage Trends and Load Forecasting Challenges

Forecasting load and operating the bulk power system becomes more complex as additional intermittent resources integrate onto the grid and customers reduce load with behind-the-meter resources. This complexity is due to the fact that shifting load from the bulk power system to behind-the-meter resources is not the same as eliminating load. When behind-the-meter resources are unavailable to produce energy, the bulk power system must act as backup and provide energy to the homes and businesses with behind-the-meter resources. NYISO must therefore consider energy provided by behind-the-meter resources when planning for the reliable operation of the bulk power system.

This trend also means that NYISO's load forecasting capability must expand to consider the impacts of electrifying other sectors of the economy, the effects of energy storage on load, factor in the impact that weather patterns may change and the likelihood that more severe weather may occur in New York State. Such improvements in forecasting should consider the impacts of changing climate conditions, including how extreme weather events may change in magnitude, duration and frequency over time.

Operational forecasting of renewable output may also become more challenging and important as intermittent wind and solar resources make up a greater proportion of NYISO supply. Generation from these resources is weather-dependent, intermittent, and difficult to predict accurately across all timescales. An example of the variability, even over long periods of time was the week of July 15-21, 2019 when there was a 36-hour period when wind resources in New York averaged only a 4% capacity factor (the actual output as a percentage of their maximum possible output). See Figure 5 below.

**Figure 5: Example of Wind Performance in the NYCA**




Source: NYISO analysis.

### Generator Interconnection Queue Process Improvements

New generation must go through a robust interconnection study process to ensure its interconnection will not adversely affect reliability. The NYISO, in coordination with the connecting utility and any potentially affected systems, assesses the reliability impacts of connecting a generator to the grid. If the NYISO identifies reliability issues, the interconnection study process identifies upgrades, estimates costs associated with those upgrades, and assigns those costs to the generator seeking interconnection to ensure the generator interconnects without degrading system reliability.

The NYISO interconnection process will need to continue to evolve to facilitate new entry as the composition of the power grid changes, and the pace of new technology development accelerates. The NYISO regularly reviews its interconnection processes and works collaboratively with its stakeholders to evaluate opportunities for improvement. In December 2017, the Federal Energy Regulatory Commission (FERC) accepted a comprehensive reform to the NYISO's interconnection processes[5] to improve the efficiency of the processes, while maintaining system reliability and the equitable treatment of developers. Subsequent to FERC's acceptance, the NYISO began implementing these process enhancements.

Having had time to evaluate the impact of the 2017 interconnection process improvements, the NYISO has undertaken a follow up interconnection queue redesign initiative. This project began in early 2019 with

5 See FERC (2017).

a thorough review of the interconnection process and improvements gleaned from the most recent 2017 process revisions. Through this review, the NYISO has identified key areas that could lead to improvements that could (1) expedite the interconnection study process overall, particularly the final study, the Class Year Study, (2) limit the possibility for unique circumstances where a single or few projects may cause delays to numerous other projects, (3) provide an alternative and/or expedited process for deliverability analyses; and (4) add additional efficiencies to the interconnection study processes. The NYISO has developed tariff revisions to implement these further process improvements as early as Class Year 2019.

In parallel with the above effort, the NYISO has developed compliance revisions in accordance with the directives of FERC Order No. 845 and Order No. 845-A. Through these orders, FERC issued a nation-wide rule adopting reforms to the pro forma interconnection processes it created through Order No. 2003 for interconnection evaluations of large generators. FERC intended for the revised procedures to provide more certainty, transparency and options for obtaining interconnection services through RTOs and ISOs. These required process changes dovetail with the comprehensive reforms the NYISO recently implemented as well as the 2019 interconnection queue redesign initiative underway to further improve the process.

### NYISO's Comprehensive System Planning Process Challenges and Enhancements

The process of transmission planning is rapidly evolving to meet the infrastructure needs of a power system with a swiftly changing resource mix. The NYISO is undertaking myriad initiatives with its stakeholders aimed at addressing the evolving nature of the electric system in New York. The objective of these initiatives is to identify potential enhancements and efficiency improvements across the NYISO's comprehensive planning process for reliability, economic, and public policy planning responsibilities. As the Edison Electric Institute (EEI) notes[6],

> **"Continued investment in transmission infrastructure will be required to maintain reliability, enhance grid security, support shifts in the nation's generation portfolio, offer greater flexibility in transmission operations with the increase in distributed energy resources, and meet public policy requirements."**

In 2018, the NYISO began an initiative to examine how to further improve its Comprehensive System Planning Process (CSPP)[7] to be more responsive to evolving reliability, economic and public policy needs. FERC has already approved one set of process changes to streamline the NYISO's Public Policy Process

6 Edison Electric Institute (2016), p. iv.
7 See NYISO (2019c).

ahead of additional public policy transmission needs that could be identified to fulfill the CLCPA, Clean Energy Standard, Offshore Wind Master Plan and other state policy initiatives.

In 2019, with significant input from and discussion with stakeholders, the NYISO is making further improvements to its reliability and public policy processes and will continue to pursue changes in 2020 to further improve its planning for reliability, economic and public policy needs. The NYISO believes that streamlining the planning processes to better inform stakeholders and policy makers about reliability, economic and public policy planning needs will allow greater flexibility to respond to changing conditions.

## Assessing Investment Challenges

### Providing Reliability and Revenue Adequacy Today

The NYISO's markets have thus far met their objective of maintaining reliable service at low cost. They have attracted and retained sufficient capacity and have maintained high operational reliability with limited out-of-market interventions.[8]

Three complementary markets for energy, ancillary services, and capacity provide the investment and price signals necessary to attract resources and promote performance aligned with system needs. Each market addresses distinctive reliability needs and is designed to meet those needs with least-cost solutions. Prices are generally set at the highest offer that must be taken in order to meet the next MW of demand. When demand on the system is high, or if lower-cost sources of supply are unavailable to the system, prices can rise. This incents performance from suppliers to meet the increased need for power. Over longer time frames, such higher price signals supports investment in new resources when and where those resources are most needed. Historically, these three markets have collectively provided sufficient revenue adequacy to attract and retain resources, and to operate them reliably.

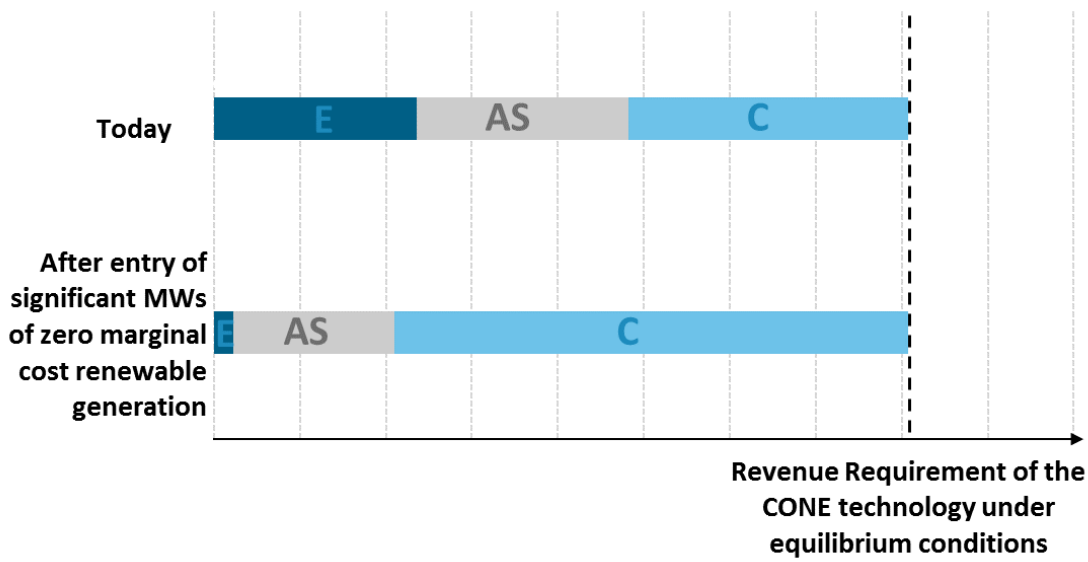
As the revenue opportunities associated with the energy, ancillary, and capacity markets change over time, a mechanism to maintain revenue adequacy for resources needed to support a reliable grid exists in the NYISO's markets. As shown in the Figure 6 below, the revenues needed to maintain resources necessary to meet reliability criteria are provided through energy, ancillary services and capacity market payments. At equilibrium,[9] total revenues equal Cost of New Entry (CONE), the annualized all-in cost at which the resource would be willing to enter the New York market. The entry of significant amounts of renewable

8 See NYISO (2018a), p. 17.

9 Equilibrium is when there are sufficient generation resources to meet load and reliability requirements, the existing generation resources are not exiting because revenue is sufficient to cover their costs, and new resources are not entering the market because the expected revenues would not cover their CONE,

resources, such as wind, may depress energy prices because such resources have variable costs near zero. However, over time capacity revenues should increase to maintain revenue adequacy if capacity is needed for maintaining resource adequacy. The capacity market is designed to perform such a function as it is structured to provide capacity revenues for needed resources through a demand curve anchored by the revenue requirements of the proxy unit. The CONE of the proxy unit is the basis for the demand curve under market equilibrium conditions.

**Figure 6: Illustration of the effect of zero marginal cost renewable generation entry on the capacity market**




### Investment Challenges that Increase in the Future

To attract needed merchant investment where generation owners bear the investment and operational risk, the NYISO's markets will evolve and continue to provide revenue adequacy through a combination of energy, capacity, and ancillary services markets. Defining the necessary grid services as products — energy, various ancillary services, and capacity — will provide opportunities to earn adequate revenues as long as the prices of those products are allowed to rise when shortage conditions increase the cost of providing those products. Allowing prices to rise when the availability of any service becomes increasingly limited not only sends correct signals for reliable and efficient operations, but also provides investors with enough revenue to prevent substantial long-term shortages of critical reliability services. When investors forecast shortage of a product, they will build those resources that are best suited to economically meet the need.

Prices act as the control signals for efficient real-time operations and to retain and attract sufficient supply. The combination of prices and associated revenue streams across all products enables the market to optimize and find the most economic portfolio of resources (each of which provides a bundle of multiple products) to meet all system needs while also satisfying policy objectives. For example, the combination of prices may favor attributes such as flexibility that can support the integration of intermittent wind and solar and devalue less flexible fossil resources.

The market's ability to achieve these goals depends on robust product definitions and pricing that must evolve and be in place as the fleet incorporates large amounts of intermittent renewable generation. Even with good market design, there will be challenges to investment that must also be addressed, as discussed in the *Enhancements to the Capacity Market* section.

#### The Challenge of Lower and More Volatile Energy Prices

Growth in subsidized, zero-variable-cost generation will put downward pressure on wholesale prices, including zero or negative prices at times when such generation is marginal. Yet prices may quickly rise when intermittent generation dips suddenly or deeply.

Low and volatile energy and ancillary services prices are appropriate as long as prices reflect underlying system conditions. Prices should be low when available supply of a product is plentiful, and prices should be high due to reserve shortage pricing when supply is limited and the use of operating reserves is required to maintain energy balance. However, long periods of lower prices may reduce the attractiveness of NYISO's markets for merchant investors, and revenues that are more volatile may increase investors' risks. Ultimately, persistently low prices are also detrimental to the viability of zero-variable-cost renewable resources such as solar and wind powered generators. Therefore, shortage pricing at times when supply is scarce allows appropriate price signals for flexible generating units to respond to changes in real-time system conditions and provides market revenues to retain and attract new resources to meet system reliability needs.

While low prices may properly reflect fundamentals, the market design needs to prevent prices from being inefficiently low, following the principles of proper price formation outlined above. For example, if additional operating reserves and energy are needed to balance unexpected reductions in intermittent generation, prices for operating reserves and energy should rise accordingly to support the needed supply. Additionally, the price of capacity could be artificially low if resources are eligible to sell more capacity than their reliability contribution to resource adequacy.

Through hedging in private bilateral markets, merchant investors and wholesale customers can manage the challenge of price volatility, while allowing generators and load to be exposed to energy and ancillary services prices at the margin to preserve the needed response for reliability. For example, the Electric Reliability Council of Texas (ERCOT) allows energy prices up to $9,000/MWh in shortage conditions potentially driven by the combination of hot weather, low reserve margins, and low wind output. The prospect of high prices provides incentives for performance, such as two summers ago when generators demonstrated very low forced outages during the hottest week of the year.[10] Yet extensive hedging going into the summer protects customers on fixed-price contracts, their retailers, and the generators financially from the fluctuations of price spikes. An alternative example of hedging can be seen in ISO-NE and PJM Interconnection (PJM). ISO-NE and PJM wanted the real-time performance incentives of ERCOT-like pricing, but did not want the risk associated with such significant price spikes. Therefore, ISO-NE and PJM bundled high shortage pricing and an enforced hedge into the capacity market in their Pay-for-Performance (PFP) and Capacity Performance (CP) market changes (for more details see the discussion below).

#### The Challenge of Declining Technology Costs

The costs of new supply technologies such as wind, solar and storage are declining rapidly. The same is also true for the cost of new flexible combined-cycle gas technologies and combustion turbines. Rapidly declining technology costs benefit customers in the long run, but create risks for investors who are looking to invest now. Such merchant investors will only invest today if they can earn near-term returns above levelized costs, with the expectation that returns will fall in the future as new, lower-cost technologies are developed.

To encourage merchant investment in technologies with rapidly declining costs, NYISO's product definitions and pricing should allow for transparent prices that enable resources to determine whether they can reasonably expect, within risk tolerances, to recover investment costs by earning sufficient revenues in the short to medium term. For example, capacity market pricing and the Net Cost of New Entry (Net CONE) may need to reflect declining future prices. Price formation should reflect underlying system needs and encourage market competition to drive prices towards equilibrium levels.

### Revenue Sufficiency With and Without Carbon Pricing

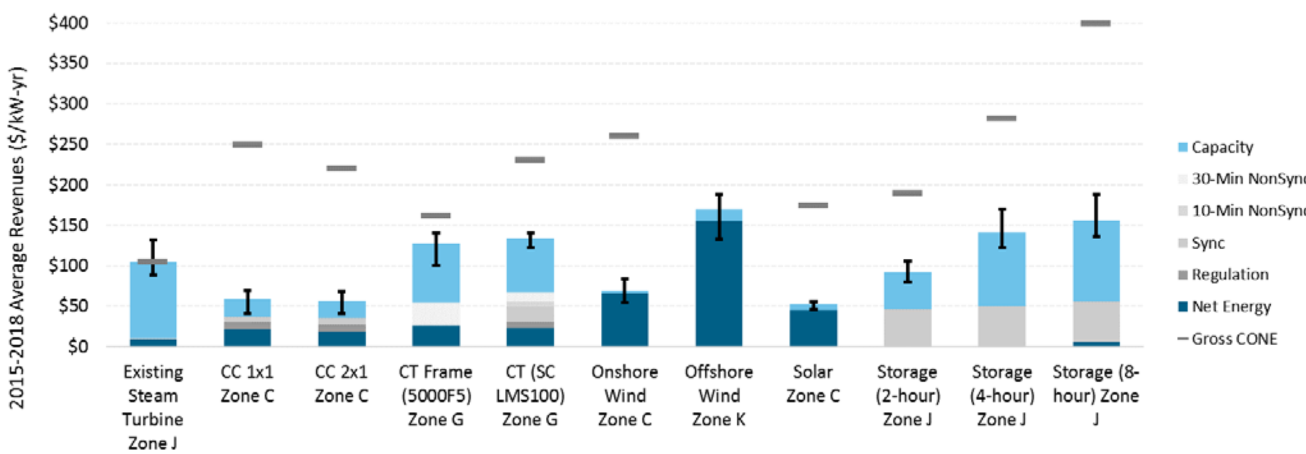
Revenue sufficiency — whether market incentives are lucrative enough to attract or retain investment when needed — is a necessary condition for reliable and economically efficient wholesale markets. When energy, capacity or other grid services are in short supply, or when they are needed, the price should increase. This will retain existing resources and attract merchant investment in new and existing resources, which will ultimately result in an economic portfolio of varied resources that can meet all system needs. Thus far, NYISO's markets have provided sufficient revenues to attract new merchant investment when needed. However, absent enhancements to NYISO's markets, policy-driven changes in the supply mix could

10 Maggio, Dave (2017).

depress prices in NYISO's markets, threatening the investability of the markets and, therefore, jeopardizing the ability of markets to efficiently meet reliability.

To provide a vision of how revenues may evolve in the future, we evaluate market revenues for several resource types under today's market design. We then *qualitatively* estimate how these revenues may change in the future with and without market design changes, including carbon pricing and additional market enhancements. A quantitative assessment of future market revenues and revenue sufficiency was also pursued through simulation modeling, as discussed below.

**Figure 7: Estimated Market Revenues by Resource and Service, 2015–2018 average**




Sources and Notes: stacked bars show simple average of market revenues across 2015, 2016, 2017, and 2018. Gross CONE for fossil units (except for the steam turbine and 2x1 CC) from Tables 17 and 22 of NYISO (2016a). 2x1 CC Gross CONE and steam turbine going forward costs (shown as Gross CONE) are from Potomac Economics (2018) Figure 14. Renewable CONE are from Potomac Economics (2018), Figure 14 and Figure A-106. Storage CONE calculated from capital costs in the New York Department of Public Service (2018), Figure 15 (applying levelized fixed charge rate from Table 23). Energy and ancillary revenues are shown net of variable costs of providing each service.

### Revenues Today

This section discusses the revenue composition of eleven resource types under NYISO's current market design, including gas-fired combined-cycle and simple-cycle plants, wind and solar, and energy storage. We evaluate, with the help of the Brattle Group, energy and ancillary services revenues with a virtual dispatch model that optimally schedules, commits and dispatches each resource against actual NYISO prices across four recent years (2015 - 2018), subject to each technology's operational constraints and costs. We also evaluate, with the help of The Brattle Group, capacity revenues based on historical capacity prices in the respective capacity zones and each resource's NYISO-assigned, derated capacity value.[11] Further details on the assumed operating parameters for each technology can be found in Appendix C.

Figure 7 summarizes the revenue each resource could have earned over the study period in specific zones. While the precise mix of revenue streams varies greatly by resource type, fossil and storage resources generally earn a greater share of revenue from the capacity market, while renewable revenues are concentrated in the energy market.

These revenues illustrate the variety of ways resources participate in NYISO's markets, and the value NYISO's markets place on its various services today. Capacity payments are the greatest source of revenues for resources that are less flexible or have higher variable costs, such as steam turbines. The energy market provides substantial revenue for technologies with low marginal costs (renewables and gas-fired combined-cycles). Ancillary services are especially important for flexible resources such as gas turbines and storage.

- **Gas-fired steam turbines** earn nearly all of their revenue from the capacity market, about 10% of revenues or $11/kW-yr in the energy market, and minimal revenues from providing ancillary services.
- **Gas-fired combined-cycles** earn about half of their revenue from the capacity market and about half from the energy and ancillary services markets. E&AS revenues include approximately $12/kW-yr in regulation and $10/kW-yr in synchronized reserve, and $50/kW-yr in energy.
- **Gas turbines** earn 50% - 60% of their revenue from the capacity market, 20% - 25% from the energy market, and 20% - 30% from providing ancillary services. Fast-ramping LMS100 gas turbines participate in regulation and synchronized reserve markets, while other gas turbines are limited to providing 30-minute non-synchronized reserves.
- **Wind and solar** resources earn nearly all of their wholesale energy market revenues in the energy market, as their derated capacity value and inability to provide ancillary services limit other opportunities. New renewable resources may be eligible to earn additional revenues from selling Renewable Energy Credits (REC) in accordance with state public policy.
- **Energy storage** is modeled as primarily operating to provide synchronized reserve. Capacity revenues depend on storage duration, with longer duration storage capturing greater capacity value than short duration (2-hour) storage. Longer duration storage provides energy arbitrage in addition to synchronized reserves.

11 Thermal units assigned class-average EFORd. Solar and wind resources assigned the default capacity ratings per NYISO (2019e). Storage resources assigned capacity ratings based on resource discharge duration (See Appendix C: Revenue Analysis Details)

All resources earned total revenues below their estimated cost of new entry over the study period, which is consistent with the current market and the oversupply of capacity.[12] This dynamic does not necessarily indicate a revenue sufficiency problem today as existing resources need only cover their going forward costs to remain in commercial operation. Furthermore, experience has shown that the market has thus far attracted investment when needed at prices below Net CONE, and maintained mandated levels of reliability.

### Revenues in the Future

Market revenues to all resources will evolve as policies drive changes in the generation fleet, with renewable resources and energy storage displacing older fossil generation and placing increasing financial pressure on nuclear resources that have large going forward costs. The concern to be further explored is that total revenues earned by new resources will be less than their cost of entry, even when the market is short the services needed to maintain reliability.

**Table 3: Illustrative Change in Future Market Prices, Relative to Today**

| Market Product | Future without enhancements (current design) | Future with enhancements and carbon pricing | Future with enhancements but without carbon pricing |
|---|---|---|---|
| Energy | ▪ Lower average prices with growth in zero marginal cost wind and solar<br>▪ Higher price volatility driven by increased forecasting error due to unpredictable wind / solar output | ▪ Prices rise with carbon pricing with fossil on margin<br>▪ Gas is likely the marginal resource most hours through 2030<br>▪ When system approaches 100% carbon dioxide free, a carbon price will not increase energy prices as gas is never marginal<br>▪ Enhanced shortage pricing better reflects system conditions and customer value<br>▪ Engaging demand reduces frequency of zero/negative priced hours | ▪ Prices rise due to enhanced shortage pricing and engaged demand-side<br>▪ Lack of carbon price somewhat limits increases in energy price |

12 Based on the gross cost of new entry or average going-forward costs assumed in Potomac Economics (2018), Appendix Section VII.A - Net Revenue Analysis.

| Market Product | Future without enhancements (current design) | Future with enhancements and carbon pricing | Future with enhancements but without carbon pricing |
|---|---|---|---|
| Ancillary Services | ▪ Prices likely similar to or lower than today<br>▪ Prices fall if products misaligned with needs<br>▪ Prices fall if storage procurements development outpaces A/S needs<br>▪ Prices rise if other dispatchable units are online less, reducing availability to provide regulation and sync | ▪ Enhanced products support reliable real-time operations<br>▪ Carbon price raises prices due to higher opportunity cost of providing ancillary services for emitting resources, raising prices | ▪ Prices rise with enhanced product definition and pricing<br>▪ Price increases less than if carbon pricing adopted |
| Capacity | ▪ Prices fall if state renewable procurements and other climate policies outpace capacity needs<br>▪ Prices rise if energy prices cause the Net CONE to rise<br>▪ Without enhancements to resource ratings, market may overstate the capacity value of renewables and storage, depressing prices | ▪ Capacity prices fall and become less important, as value shifts to operational E&AS products (but could still be high if E&AS signals are not increased and if low marginal capacity value of renewables is recognized)<br>▪ Prices may fall as zero-emitting capacity resources recoup a greater share of costs from the energy and ancillary services market | ▪ Lack of carbon pricing means energy prices are lower and capacity plays a more important role in the revenue outlook of new resources; capacity prices rise correspondingly |

A detailed quantitative assessment of future market revenues and revenue sufficiency might also be undertaken to further inform the necessary market design changes needed to allow the markets to continue to support grid reliability. Future work would model price and revenue dynamics into the future as the system evolves, taking into consideration state policies, the design of existing and new market products, and resource costs.

Table  illustrates how market prices may change in the future depending on enhancements to NYISO's market products. We consider three possible scenarios for the design of the NYISO market.

1. Current market design without enhancements
2. Enhanced market design with carbon pricing and additional enhancements
3. Enhanced market design without carbon pricing and additional enhancements

Changing prices will affect each resource type's revenues in different ways, depending on the types of services they are capable of providing and their carbon dioxide emissions. Without reforms, revenues may decrease to all resource types across all market products. Carbon pricing may increase energy and ancillary services revenues to resources such as renewables, energy storage and gas-fired combined-cycles that typically emit less carbon dioxide than the marginal resource and can thus profit from higher energy prices. Additional ancillary services market product and pricing enhancements may further increase revenues to flexible resources such as energy storage and gas peakers that provide grid services needed to balance intermittent renewable resources.

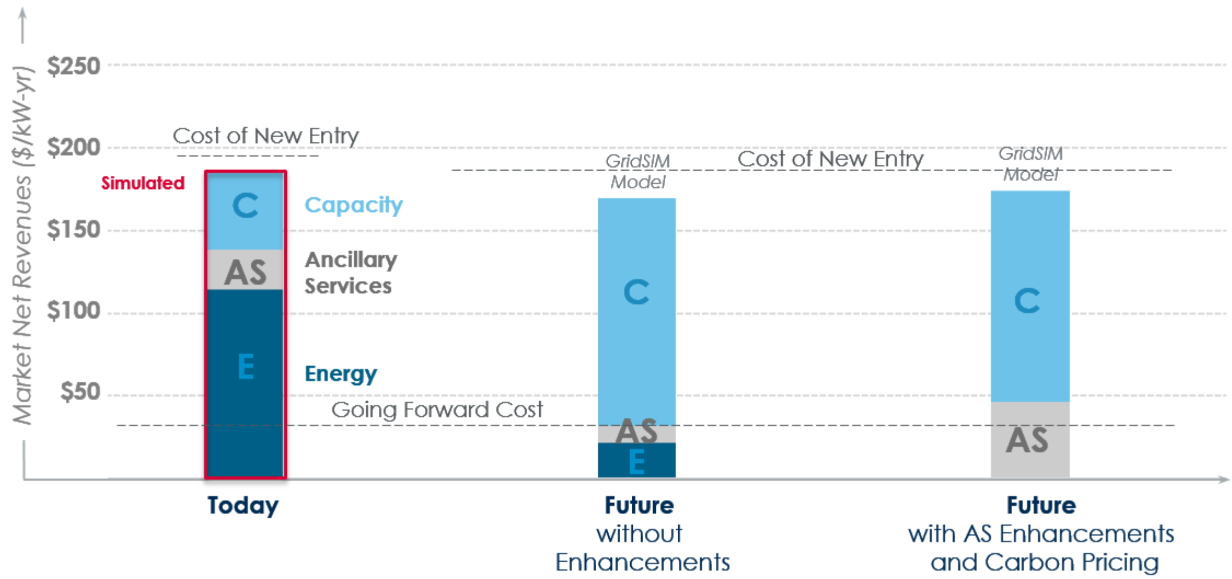
Figures 8 and 9 illustrate these changing market for a downstate existing frame gas simple-cycle resource and for a downstate two hour storage resource. The left most bar shows the simulated revenues the resource could get in today's market (with the existing fleet). The next two bars show a 2030 future without enhancements and a 2030 future with enhancements (AS changes and carbon pricing). The modeling of the future includes the CLCPA's goals including accounting for the entry of renewable resources and the retirement of some existing resources.[13]

In Figure 8, the future simple-cycle unit revenue sources shift from predominantly energy and AS revenues to capacity market revenues due to additional renewable resources 1) driving down energy prices reducing energy revenues when the unit is online, and 2) reducing the number of hours in which the unit operates and earning energy revenues. In the future with AS Enhancements and Carbon Pricing, the simple-cycle unit shifts to primarily being used to provide ancillary services to capitalize on the unit's flexibility. In today's market the simple-cycle resource does not earn sufficient revenues for new entry, but earns sufficient revenue to cover Going Forward Costs This trend continues into the future, with or without AS Enhancements and Carbon Pricing.

Figure 9 illustrates how a 2-hour storage resource may experience an increase in energy and AS revenues in the future as flexibility becomes more valuable and as diurnal patterns provide opportunities for energy arbitrage. Today's markets do not provide sufficient revenues to cover the Cost of New Entry for energy storage. In the future, falling costs of storage coupled with increasing energy and ancillary service revenues may lead to economic new entry.

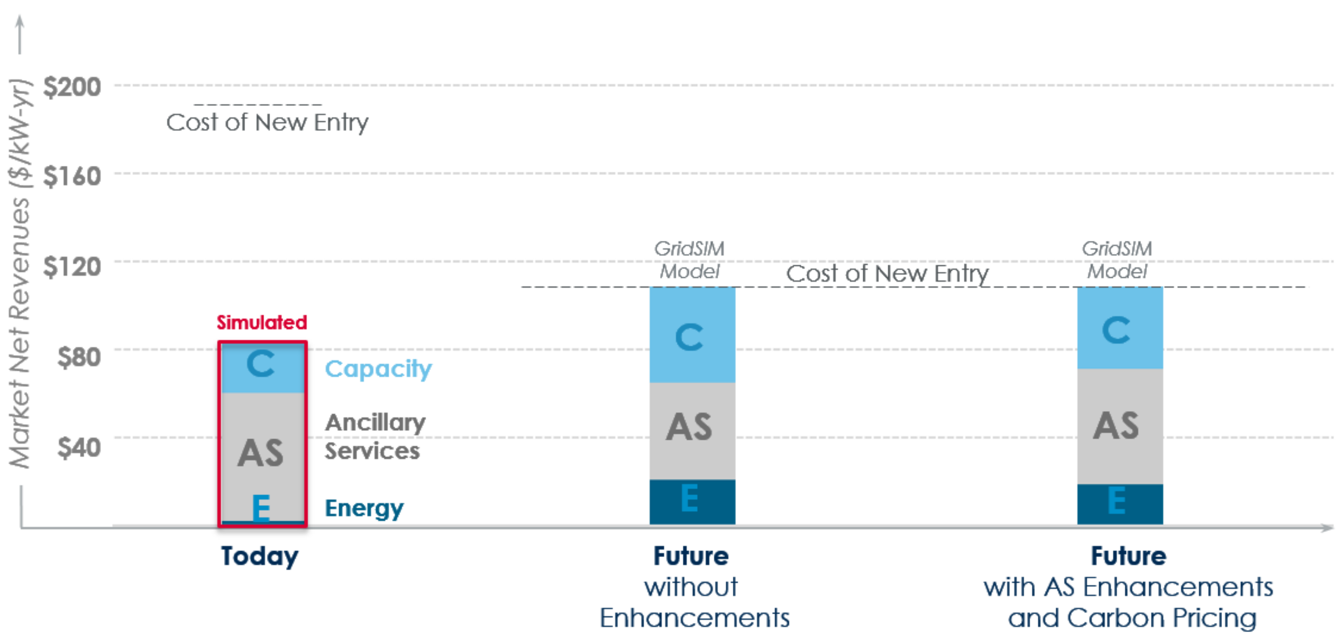
13 Appendices C and D provide more information on the assumptions behind the analysis.

**Figure 8: Illustrative Change in Revenues, Existing Downstate Frame Gas Simple-Cycle**




Sources and Notes: All values in 2030$. "Future" stacked bars show estimated potential market revenues in 2030, given the legislative climate goals outlined in New York State Senate (2019). Revenue estimates derived from system modeling conducted by The Brattle Group. See Appendices C and D for assumptions about resource costs, including Gross CONE. Energy and ancillary revenues are shown net of variable costs of providing each service.

**Figure 9: Illustrative Change in Revenues, 2-Hour Duration Downstate Energy Storage**




Sources and Notes: All values in 2030$. "Future" stacked bars show estimated potential market revenues in 2030, given the legislative climate goals outlined in New York State Senate (2019). Revenue estimates derived from system modeling conducted by The Brattle Group.. See Appendices C and D for assumptions about resource costs, including Gross CONE. Energy and ancillary revenues are shown net of variable costs of providing each service.

## Market Considerations

As discussed above, NYISO's energy and ancillary services markets have a proven track record of supporting reliable operations and robust price formation. However, continued success will require enhancements to NYISO's energy and ancillary services products, including enhancements to product definitions and pricing. Product definition enhancements may include revising existing products or creating additional products to efficiently manage growing ramping challenges and uncertainty. Quantity and pricing enhancements may also be needed to the extent current products do not fully reflect marginal costs and shortage values and/or the marginal value of consumption by customers.

Absent enhancements, reliable operations and/or investability of NYISO's markets may become threatened. Operators may increasingly rely on out-of-market actions to maintain reliable operations. Average prices may fall to unsustainably low levels as zero-variable-cost renewables increasingly become the marginal, price-setting resources, and thus markets may not attract the right type or quantity of resources to help balance the real-time variability of such intermittent resources or supply the grid when these intermittent resources are not available. Finally, prices in the energy market may be insufficient to animate the demand-side. New York's Reforming the Energy Vision recognizes that market participation from demand-side resources will play a very important role in maintaining reliable operations and robust price formation.

The NYISO has identified several potential market design enhancements at various stages of development in Table . Several are already underway with implementation expected in the next few years, some are new efforts being considered by stakeholders where enhancements to the market design are likely, and others require further study and discussion with stakeholders before proposing any specific enhancements. While each of these efforts addresses the concerns and follows the principles outlined above, they must fit together coherently and efficiently satisfy New York's grid reliability needs.

**Table 4: Potential NYISO Market Design Enhancements**

| Market Enhancement Opportunity | Description | Status |
| --- | --- | --- |
| **Energy & Ancillary Services Market Opportunities** | | |
| Carbon Pricing | Internalize the societal cost of carbon dioxide emissions via a $/ton charge to participants in the Energy and Ancillary Services markets. | Ongoing Effort |

| Market Enhancement Opportunity | Description | Status |
|---|---|---|
| Enhance Energy and Shortage Pricing | Enhance energy and shortage pricing such that prices are consistent with reliable grid operations up to customers' value of lost load and probability of outage as supply conditions tighten and with smoother demand curves. Ongoing efforts include:<br>■ Ancillary Services Shortage Pricing<br>■ Constraint Specific Transmission Shortage Pricing<br>■ Enhanced Fast Start Pricing | Ongoing Effort |
| Review Energy and Ancillary Services Product Design | Further analysis to evaluate whether today's ancillary services products will continue to support reliable operations and investment signals as the system evolves. Ongoing efforts include:<br>■ More Granular Operating Reserves<br>■ Reserve Enhancements for Constrained Areas<br>■ Reserves for Resource Flexibility | Ongoing Effort |
| Evaluate Forecasting Approaches | Wind, solar, and load forecasting may become more challenging as wind and solar deployments grow. | Under Consideration |
| Improve Intertie Scheduling | Evaluate how more frequent and timely scheduling of the interties can support New York's reliability challenges. | Under Consideration |
| Improving Fuel and Energy Security | Create incentives so that resources will invest in and maintain energy supply arrangements and/or alternative fuel capabilities to meet reliability and enhance grid resilience. | Under Consideration |
| Engaging the Demand-Side | Allow load participation to set price in the real-time energy market and have a greater role in providing reserve and regulation in short-term operations. | Investigate |
| Evaluate Changes to the Energy Market Construct | Improve resource incentives for remaining flexible throughout the day ahead to real-time scheduling horizon. Initiatives to consider include:<br>■ Consider introducing a third settlement between the Day-Ahead Market (DAM) and the real-time market (RTM)<br>■ Changes to DAM and/or RTM look-ahead time horizon or intervals | Investigate |

| Market Enhancement Opportunity | Description | Status |
|---|---|---|
| **Capacity Market Opportunities** | | |
| Comprehensive Mitigation Review | A holistic evaluation of the BSM rules and methodology to evaluate how to modify NYISO market structures in a balanced manner that preserves competitive price signals and economically efficient market outcomes required to maintain system reliability and supports the Climate Leadership and Community Protection Act (CLCPA) goals. | Ongoing Effort |
| Enhancements to Resource Adequacy Models | Evaluate the robustness of NYISO's resource adequacy models and make updates as needed to reflect emerging technologies and changing system dynamics. | Ongoing Effort |
| Revise Resource Capacity Valuation to Reflect Marginal Reliability Contribution | Develop enhanced capacity ratings for all supply resources that reflect the marginal contribution to meeting resource adequacy criterion, accounting for system dynamics, resource availability and performance (including the impact of outage correlations). Ongoing efforts include:<br>▪ Expanding Capacity Eligibility<br>▪ Tailored Availability Metric | Ongoing Effort |
| Capacity Demand Curve Adjustments | Incremental adjustments to the capacity demand curve, including the shape and slope, to ensure resource adequacy and price stability as system conditions evolve. | Under Consideration |
| Ensuring Year-round Resource Adequacy | Consider procuring different amounts of capacity in each seasonal auction that reflect the underlying capacity need in that season. | Investigate |
| Enhance Capacity Market Pricing | Consider ways to optimize the capacity procurements at locations throughout the state and establish locational capacity prices (C-LMP) that reflect the marginal capacity value at these locations. | Investigate |

### Enhancements To The Energy and Ancillary Services Markets

The NYISO recommends an approach that emphasizes energy and ancillary services products and market pricing that are reflective of system conditions and operational needs. Shortage pricing, sending appropriate price signals when supply is short and unable to meet the reliability needs of the system, including energy and ancillary services, is particularly important to provide incentives for generating units to respond to in real-time needs and to signal investment. Real-time shortage pricing enhancements are preferable to incenting grid flexibility because real-time prices can reflect varied and dynamic operational needs of the actual grid.

Some additional detail is provided in the following section on selected market enhancement opportunities.

### Ongoing NYISO Efforts

The recommendations in this section are well defined efforts that are being pursued by the NYISO with the support of its stakeholders.

#### Carbon Pricing

In 2017, the NYISO and the New York Department of Public Service initiated a public stakeholder process to evaluate the implications of carbon pricing on NYISO's markets. Under the NYISO's proposal, suppliers would be charged for each ton of carbon dioxide emissions associated with internal generation at a price per ton established by the PSC. Suppliers would in turn add this cost in their energy offers, and LBMPs would increase, based on the price per ton times the emissions rate of the marginal price setting resource. In order to prevent the distortion of regional power flows, imports would be charged and exports credited with the carbon impact to the LBMP.[14] Costs to load-serving entities would not increase in the long run, however, largely because carbon charges would be disbursed back to customers.[15]

Carbon pricing would internalize the externality of carbon dioxide emission costs within NYISO's existing wholesale markets such that the markets will support efficient investment and operations consistent with both New York's decarbonization goals and NYISO's reliability requirements. This is not to say that New York State's current approach to incentivize decarbonization primarily through the use of REC and the RGGI program is entirely incompatible with wholesale markets. The RGGI program does begin to internalize the externality of carbon dioxide emissions. REC pay for just the clean attribute that is unrelated to grid-services attributes reflected in the NYISO wholesale markets, but REC nonetheless reflect a price related to clean energy. However, the state's current REC construct is not resource-neutral, does not signal decarbonization opportunities within the fossil fleet, does not align retail and wholesale prices to incent efficient demand-side responses to environmental externalities, and does not incentivize new clean energy resources to site in locations/generate at times that displace the most carbon. Carbon pricing would incentivize these beneficial outcomes.

14 See NYISO (2018c).

15 See Newell, Tsuchida, Hagerty, Lueken, and Lee (2018).

In addition, carbon pricing would incentivize competition from among low-cost sources of carbon dioxide abatement and consequently reduce the total economic cost of meeting New York's decarbonization goals. Carbon pricing would invite a broader, more competitive range of solutions than targeted procurements under the CES alone. Higher carbon prices would provide a stronger market signal than current RGGI prices and reward efficiency improvements across the fossil fleet, incentivize conservation and energy efficiency, encourage storage and other technologies that can reduce emissions, and lead to other market responses and innovations that are difficult to predict. More explicit carbon pricing would make REC procurements more effective by amplifying the rewards for clean energy produced at times and locations that reduce emissions the most, potentially achieving more carbon dioxide abatement from the same quantity of procured REC. It could tilt any new investment in traditional generation toward the lowest-emitting technologies. It could also support the continued operation of the upstate nuclear fleet — among New York's largest source of carbon-free generation — after the ZEC program expires.

#### Enhanced Shortage Pricing

NYISO could enhance existing energy and shortage pricing in order to align prices with reliable grid operations up to customers' value of lost load and probability of outage as supply conditions tighten. NYISO must consider how changes to existing ancillary services shortage pricing would affect flows to and from neighboring systems in various shortage events. One set of changes could include a more graduated set of prices as the system becomes shorter on reserves, such that price signals could be sent in advance of reserve supply falling below the minimum reserve requirement.

Several ongoing NYISO efforts partially address the need for enhanced shortage pricing, including:

- Ancillary Services Shortage Pricing
- Constraint Specific Transmission Shortage Pricing
- Enhanced Fast Start Pricing

#### Review Current E&AS Product Design

NYISO intends to conduct analyses to evaluate whether today's energy and ancillary service products will continue to support reliable operations and investability as the system evolves. If that is not the case, the NYISO will evaluate the need for new products and the potential for increasing current ancillary services requirements that would have the effect of providing incentives for more flexible resources to be retained or attracted as new entry. The NYISO has several ongoing projects to review energy and ancillary services product design[16], which include:

- More Granular Operating Reserves
- Reserve Enhancements for Constrained Areas
- Reserves for Resource Flexibility

### Efforts Being Considered

The recommendations in this section are fairly well defined bodies of work that are being considered by the NYISO and its stakeholders to study and potentially prioritize in the coming years.

#### Evaluate Forecasting Approaches

Operational forecasting may become more challenging as intermittent wind and solar resources make up a greater proportion of NYISO supply. Generation from these resources is intermittent and difficult to predict accurately across all timescales. Furthermore, electrification of new types of loads and more dynamic load resources may also make forecasting load more challenging. NYISO's Climate Change Impact and Resiliency Study is one ongoing effort to better understand these challenges.[17] That effort will continue in 2020 with reliability assessments of future system conditions, considering potential impacts from climate change while seeking to achieve the goals of the CLCPA through 2040.

#### Improved Intertie Scheduling

Improved scheduling and optimization of NYISO's interties will become increasingly important as the need for fast-responding supply resources grows. NYISO should evaluate the need for more frequent scheduling of the interties (currently every 15-minutes on most interfaces versus 5-minutes for internal supply resources).

#### Improving Fuel and Energy Security

New York's power grid anticipates facing increased challenges associated with the generating fleet transitioning in response to economic, environmental, and public policy considerations. Increased dependency on natural gas and intermittent technologies creates an elevated risk to system reliability if those fuel supplies were to be interrupted. Earlier in 2019, the NYISO engaged the Analysis Group to conduct a study to help identify the types and magnitudes of potential near-term concerns that could arise by examining various scenarios that place strains on fuel and energy security in New York. Based on this analysis, the NYISO will be enhancing its monitoring capabilities and will continue to monitor key factors related to energy and fuel security.

16 For more details on any of the projects in these sections, please see NYISO (2019a).
17 See NYISO (2019b).

In the future, the NYISO may consider incentives that support investment in and maintenance of energy supply arrangements and/or alternative fuel capabilities to meet reliability and enhance grid resilience depending on findings of the Analysis Group study.[18]

### Efforts that Require Investigation and Careful Consideration

The recommendations in this section require further investigation and discussion with stakeholders and policy makers before the scope of the effort is well defined.

#### Engaging the Demand-Side

Engaging load participation will become increasingly important as deployments of intermittent wind and solar resources rise to support New York's decarbonization goals. Today, supply resources are dispatched by NYISO to meet load that has limited flexibility. From an operations perspective load is seen as "uncontrollable" whereas generation resources are considered controllable. Eventually, controllable and flexible load may be desirable to balance inflexible/intermittent supply and provide ancillary services. Alternatively, enhancing the sloped and smooth shortage pricing curves, could provide many of the benefits of allowing loads to set prices through the ability of price taking load to decide when to economically reduce consumption in response to higher energy market prices.

Without engaging the load participation in price formation in the energy market, prices may become bimodal: zero or negative in many hours that exhibit oversupply conditions, and very high in occasional shortage hours due to reserve shortage pricing. Engaging load participation allows for more robust price formation that reflects customers' willingness to pay, consistent with their marginal benefit of consuming energy.

Moreover, load participation can become a more active player in the ancillary services markets by providing 10-minute and 30-minute reserves and even providing regulation and frequency response through the aggregated control of appliances and loads that do not need to run at all times. In this way demand can provide system control when greater amounts of energy are provided by uncontrollable intermittent resources that are unable to provide these essential reliability services in real-time operation.

Multiple challenges exist prior to engaging load participation. Most customers are not exposed to real-time prices; customers see flat prices or time of use rates that do not reflect real-time market prices or operational conditions. This is largely a ratemaking question  under the purview of utilities and the Public Service Commission. Another challenge is the need for the load to have interval metering and appropriate

18 See Analysis Group (2019) for the MIWG update.

technological platforms and communication infrastructure in place to provide ancillary services and to respond to real-time energy market prices.

NYISO's markets currently do not allow customer loads to set prices in real time. Enabling loads to set prices is not a trivial change to NYISO market design and operations, but will be essential for reliability, efficient price formation, and investability. In the near term, the benefits in terms of customer participation and price formation are unclear. However, long-term trends point towards more customer engagement as technology supports more load interactivity and the challenges of balancing wind and solar resources grow. This is apparent in the VDER Tariff, recently approved by the PSC, which compensates DER at NYISO's locational wholesale energy market prices. The next step would be to integrate DER into the NYISO market design, which was recently approved by NYISO's Management Committee[19] and is currently planned for fall 2021, as a first step toward a fully integrated load participation with resources that respond to, and sets, prices.

#### Evaluate Changes to the Energy Market Construct

Improve incentives to encourage resource flexibility throughout the real-time scheduling horizon.

#### Changes to the Settlements of the Energy and Ancillary Services Markets

The NYISO currently operates a two settlement market, with a DAM that runs the morning prior to the operating day and a RTM that includes of the Real-Time Commitment software (RTC) which sets interchange schedules and determines whether additional economic resource commitments are necessary, and the Real-Time Dispatch software (RTD) which dispatches internal resources and establishes settlement clearing prices.

When system conditions between RTC and RTD change, which can be quite often, the interchange and commitment decisions may not be supported by the final RTD clearing prices. This disconnect can create disincentives for efficient real-time market behavior that may require additional out-of-market actions. Additionally, as more weather-dependent resources impact the day-ahead commitments and/or real-time operations, RTC may need more flexibility to decommit unnecessary generators based on projected system conditions. Settling these decisions on RTC prices might offer improvements to real-time market efficiency and reduce overall costs for consumers.

The NYISO should also examine the benefits of a third settlement either before the current DAM or between the DAM and RTC.

19 See NYISO (2019d) for more information.

#### Changes to the Time Horizon or Time Intervals of the Day-Ahead and/or Real-Time Markets

The DAM is an hourly market that optimizes over the 24-hours in the day. The RTM requires offers at least 75-minutes prior to the operating hour, RTC schedules in 15-minute intervals and looks out over a nominal two-and-a-half hour period, and RTD dispatches in 5- or 15-minute intervals and nominally looks out between 55- and 65-minutes.

As the load shape changes with the addition of energy limited resources such as batteries, as well as solar and other renewable resources, the real-time markets may need to consider shorter bid-lock windows, and look out further or with more granular intervals in order to correctly dispatch resources with limited energy capabilities or weather-dependent energy capability. Separately, 15-minute intervals in the DAM should be investigated further to allow for more flexibility within the hour for commitment and decommitment decisions.

The NYISO should consider if changes are needed to the time horizon of the day-ahead and intra-day RTC/RTD energy markets and/or to the intervals they use.

### Enhancements to the Capacity Market

New York continues to rely on merchant investment to provide adequate resources to keep the lights on as the grid decarbonizes. Attracting and retaining sufficient resources that can perform when needed requires a robust set of market mechanisms, including both the E&AS markets and the capacity market.

The NYISO's energy and ancillary services markets, particularly with the enhancements described above, will differentially reward the resources that can most efficiently and effectively serve evolving operational needs — whether that means generating more during shortages or ramping more quickly during ramp-limited periods. However, the energy and ancillary services markets alone do not provide enough revenue to attract sufficient investment to meet NYISO's traditional "1-day-in-10-years" (1-in-10) resource adequacy standard[20]. Thus, capacity markets will continue to be needed to provide the additional revenue stream to support adequate investment to maintain the required levels of resource adequacy. As the fleet transforms and creates new challenges, ongoing efforts will be needed to ensure capacity auction design continues to support adequate investment.

#### Ensuring Resource Adequacy as the Grid Changes

The current capacity market primarily ensures sufficient "resource adequacy," or that enough MW are installed to meet peak demand. This definition is a reasonably accurate proxy for achieving the reliability

20 The 1-day-in-10 years resource adequacy standard refers to a reliability standard where involuntary regional losses of load events are allowed only one day every ten years. Duration or extent of the loss of load event is not considered, only the number of days which experience loss of load events.

standard that allows involuntary losses of load events no more than one day every 10 years (or 0.1 days per year on average) in a system comprised of mostly dispatchable generators and reliability risks focused on a handful of peak load hours. It is an increasingly more complicated to maintain compliance with this standard in a future characterized by high levels of non-dispatchable, variable wind and solar generation, as resource adequacy challenges shift to a wider set of hours. Reliability challenges will become more dynamic, driven by periods of very low wind and solar resource output, and by rapid or unexpected changes in output. The resource adequacy challenge becomes attracting and retaining enough flexible resources that are able to maintain reliable service during those events. In this sense, the capacity product is one that starts to look like a physical reliability call option that can be called upon for more than just a few peak hours, but at any time when the supply-demand balance approaches shortage conditions, whether it is due to high load or lack of supply. In this sense, maintaining reliable service during events where there is more demand for electricity than supply may in the future depend more on commitments to load reductions and dispatchable storage than has been the case in the past.

Currently, the Installed Reserve Margin (IRM) is set annually by the New York State Reliability Council (NYSRC) as a percentage of the forecasted peak load for the year, and establishes the minimum amount of Installed Capacity (ICAP) that must be on the system throughout the year. In a future with high penetrations of wind and solar, a capacity construct focused primarily on having enough MW available (plus a reserve margin[21]) may miss these increasingly diverse reliability challenges. Today's capacity products will need to improve the methods used to measure capacity for all resource types to better align reliability needs throughout the year.

### Ongoing NYISO Efforts

The recommendations in this section are well defined efforts that are being pursued by the NYISO with the support of its stakeholders.

#### Comprehensive Mitigation Review

The ICAP market has undergone significant changes in both design and resource mix since the NYISO's BSM measures were first implemented in May of 2008. While there have been many incremental changes to align mitigation measures with changes in the market, there has not been a holistic evaluation of the

21 Currently, the Installed Reserve Margin (IRM) is set annually by the NYSRC as a percentage of the forecasted peak load for the year, and establishes the minimum amount of ICAP that must be on the system throughout the year. The IRM is established through a study that considers the amount and types of capacity on the system, hourly generation profiles for intermittent resource types, Monte Carlo simulations for forced outages on traditional resource types, an hourly forecast load model along with scenarios that capture load forecast uncertainty, and a transmission model. Together, these inputs are used to measure the likelihood that a loss of load event may occur during any given hour of the study year. The NYSRC then increases the IRM to ensure that the probability of a loss of load event remains below 1-in-10, or, 0.1 days/year, for every hour of the year. In 2019, the NYSRC set an IRM of 117% of the forecasted peak coincident load for New York State of just over 32,000 MW, establishing that there must be over 37,000 MW of ICAP available at all times to stay in compliance with the 1-in-10 requirement when considering contingencies and variability in supply and demand. For the 2019 IRM study, please visit: http://www.nysrc.org/pdf/Reports/2019%20IRM%20Study%20Body-Final%20Report[6815].pdf

BSM rules and methodology to evaluate whether the current framework will be adequate in a future with significant renewable resources and policy objectives that impact the capacity market. The BSM rules were originally developed to evaluate traditional generation technologies, but new resource types such as energy storage, renewable generation and DER are fundamentally different in design and operation. Additionally, these resources are more likely to be used to meet policy goals or promote environmental attributes than traditional generator technologies. For further discussion of this topic please see the section below titled *Preserving Competitive Outcomes in the Capacity Markets*.

#### Enhancements to Resource Adequacy Models

The NYISO is continuously evaluating the accuracy and robustness of its underlying resource adequacy models, reliability metrics and probabilistic tools, and updating them to incorporate changing characteristics of the power system and resource fleet.

#### Revise Resource Capacity Valuation to Reflect Marginal Reliability Contribution

Today's capacity market assigns derating factors to resources through technology-specific rules that generally reflect their recent average level of availability. These derating factors are used to discount the amount of ICAP that a resource can sell into the capacity market — (the Unforced Capacity (UCAP) the resource can sell. The current capacity market uses UCAP, instead of ICAP, as the commodity that is bought, sold, and used to meet requirements and maintain reliability. Derating factors effectively remove a portion of a generator's ICAP that may not be dependably relied on as shown through history, averaged over time, so that there is more confidence that the remaining UCAP can be relied upon for resource adequacy.

As reliability risks shift from peak demand hours to a more complex and diverse set of hours, resource ratings will need to evolve as well. Improved resource ratings are essential in a system that is increasingly reliant on intermittent resources and more complex reliability challenges.

Ideally, resource ratings should reflect the marginal contribution to reliability, such that all resources provide the same value per rated MW. This enables competition among technologies with different availability schedules. It also provides for consistent accounting in checking to see that sufficient resources have been procured to meet the 1-in-10 standard, even if some resources provide less value per nameplate MW than an always-available resource.

For generation output from intermittent resources whose output is highly correlated (for example, wind resources that are located relatively close to each other), the approach of calculating average output over defined "performance hours" currently used for wind and solar resources may not accurately reflect marginal reliability value or the actual supply available to meet peak demand. In a high-renewable system, these highly correlated resources can leave a big gap in supply if they all fail to generate simultaneously, i.e., when the wind stops blowing or the sun does not shine across large swathes of the state. Such conditions can result in the tightest supply conditions of the year when reliability is most threatened. Therefore, the performance of intermittent resources in the hours with the tightest supply conditions should be considered when establishing resource capacity ratings

This problem of correlated performance affecting the resource's reliability contribution is an important feature of renewable generation, but it arises with other resources types as well. Even dispatchable generation can experience common-mode failures that decrease their marginal reliability contributions, which is also unaccounted for in current approaches. For energy-limited storage resources and demand response, the marginal reliability value depends on unique characteristics in ways that are not easy to capture with simple indicators.

Without enhancements to recognize such issues, current approaches to assigning capacity ratings may not accurately reflect each resource's marginal reliability contribution and result in attracting and retaining the wrong mix of resources.

Accordingly, the NYISO recently established new derating factors for duration-limited resources and is currently evaluating the resource ratings of all other resource types. NYISO has multiple ongoing projects that partially address this need, which include:

- Expanding Capacity Eligibility
- Tailored Availability Metrics

NYISO could undertake a more extensive effort to develop enhanced ratings for all resources that better reflect marginal contribution to reliability, accounting for system dynamics, correlations, and intermittency. One potential quantitative approach is to use Effective Load Carrying Capability (ELCC) to set resource ratings.[22] Quantifying the ELCC of supply resources requires more sophisticated modeling to estimate the marginal reliability value of supply resources, accounting for the distribution and correlation of generation from intermittent and energy-limited resources.

As with all administratively-determined parameters, ELCC ratings are imperfect and depend upon modeling choices and assumptions. However, ELCC methods are increasingly utilized for determining solar and wind resource capacity values in other jurisdictions, including the Midcontinent Independent System Operator (MISO), California Independent System Operator (California ISO), and several utilities experiencing significant renewable resource additions (Portland General Electric and Xcel Energy

22 The ELCC of a generator is defined as the amount by which system load can increase when a generator is added to the system while maintaining the same level of system reliability. System reliability can be measured using loss-of-load expectation (LOLE) or loss-of-load probability (LOLP).

Colorado). As fleet changes may occur rapidly in order to meet policy goals, resource ratings should be regularly re-evaluated to ensure that ratings accurately reflect future marginal reliability contributions.

A benefit of today's resource rating approach is its transparency; dispatchable resources receive ratings reflective of their forced outage rate, and intermittent resources receive ratings reflective of their average output during peak periods. More sophisticated ELCC approaches run the risk of making the resource ratings more opaque and controversial, with direct implications for supplier revenues. Another possible approach, how to better align derating factor with LOLE risk, is currently being examined by the NYISO.

### Efforts Being Considered

The recommendations in this section are fairly well defined bodies of work that are being considered by the NYISO and its stakeholders to study and potentially prioritize in the coming years.

#### Capacity Demand Curve Adjustments

The capacity demand curve establishes the quantity of capacity purchased and the price that is paid for that supply in the spot auctions, and therefore through the various other auctions. Incremental adjustments to the capacity demand curve may be needed to provide sufficient resource adequacy as system conditions evolve. Although the NYISO's Demand Curve Reset (DCR) process considers the shape and slope of the demand curve, the NYISO recommends a targeted effort to review the efficacy of the shape and slope used in the ICAP market.

### Efforts that Require Investigation and Careful Consideration

The recommendations in this section require further investigation and discussion with stakeholders before the scope of the effort is well defined.

#### Locational Marginal Pricing of Capacity

The 1-in-10-year resource adequacy standard can be met with various combinations of capacity in different areas of the New York Control Area. The DCR process sets the capacity demand curve for each locality relative to the IRM/LCR without fully considering whether this results in a consistent relationship between the clearing prices of capacity and the marginal reliability value of capacity in each Locality. The NYISO implemented improvements to how LCRs are set in 2018, but the resulting capacity procurements and prices could be more efficient if they were to fully reflect the marginal reliability value of capacity provided by individual resources. Reliance on four fixed capacity zones can also prevent the current market from responding to significant resource additions, retirements, or transmission network changes because the localities may not be sufficiently granular.

A capacity market pricing framework where the procurements and clearing price at each location is set in accordance with the marginal reliability value of capacity at that location should be investigated. Locational Marginal Pricing of Capacity (C-LMP) would eliminate the existing capacity zones and clear the capacity market with an auction engine that can include planning criteria and constraints. This could optimize the capacity procurements at locations throughout the state, and establish locational capacity prices that reflect the marginal capacity value at these locations. This proposal may reduce the cost of satisfying resource adequacy needs, facilitate efficient investment and retirement and be more adaptable to changes in resource mix (i.e., increasing penetration of wind, solar, and energy storage) though it can also result in volatile capacity prices that are difficult to forecast.

#### Ensuring Year-Round Resource Adequacy through Dynamic Capacity Requirements

NYISO requires that the same quantity of ICAP is purchased year-round in each monthly spot auction, based on the year's forecast peak load that, in New York, occurs during the summer. In other words, the amount of capacity that must be purchased does not change from month to month or season to season within a Capability Year, but instead is based on the forecast peak load for the Capability Year. NYISO could consider procuring different amounts of capacity during the Summer and Winter Capability Periods that reflect the underlying capacity need in that season. Procuring only the needed quantities of capacity will avoid paying for capacity that is not needed, better signal investment in resources that provide capacity in seasons in which it is needed, and allow the capacity auction to maintain year-round reliability, even if NYISO becomes a winter-peaking system due to electrification of the heating sector. Additionally, dynamic capacity requirements could help to better "match" capacity requirements with shifting load shapes on a more granular basis to better account for the seasonality of intermittent generators and their ability to support resource adequacy at different levels throughout the year.

## Preserving Competitive Outcomes in the Capacity Markets

The NYISO markets, including the ICAP market, have achieved significant benefits for New York consumers over the last twenty years. At this time, the markets are facing new challenges prompted by a changing resource mix driven in large part by New York State environmental policies. The NYISO supports review of New York's current resource adequacy procurement model, including modifications to its existing buyer-side mitigation framework. As the NYSRC has stated in its initial comments in the PSC's Resource Adequacy proceeding, "[t]he intermittent nature of renewable resources create challenges with regard to both the planning and operation of the state's bulk power system."

Specifically, the NYISO acknowledges the need to better harmonize the wholesale markets with state environmental policies, in particular those embodied in the CLCPA, while maintaining competitive price signals. The effort should include an evaluation of adjustments to the NYISO's capacity market buyer-side mitigation rules to address conflicts with state policy objectives.

Currently, the NYISO is in the early stages of considering a variety of potential market design changes ranging from modest adjustments to its resource adequacy framework to more fundamental alterations to its market and mitigation rules. The NYISO will be working with stakeholders and policymakers to identify a preferred reform proposal. The NYISO has not pre-judged any alternatives and looks forward to better understanding the views of stakeholders in shaping an approach that will work for New York. As noted above, the NYISO's comprehensive mitigation review project will assess options to evolve the BSM rules to better reconcile them with state environmental policy.

## Planned Market Design Changes

The NYISO has worked with its stakeholders to prioritize no regrets market changes for 2020 and develop the 2019 Master Plan. Separately, many of the opportunities identified in this report require further investigation by the NYISO and collaboration with its stakeholders. For 2020, the NYISO will produce three study reports that will further inform stakeholder and policymaker understanding of potential bulk electric grid challenges that may be encountered as the public policies are achieved. First, the Congestion Assessment and Resource Integration Study (CARIS) report will include a simulation of what the grid may look like in 2030 with 70% end-use energy sourced from renewables; this will identify potential bottlenecks in the transmission system that could restrict consumer access to renewable energy. Second, the Reliability Needs Assessment will include a similar evaluation of 70% renewable energy in 2030, with a focus on identifying potential risks to system reliability. Third, the Climate Change Impact and Resiliency Study will focus on identifying necessary attributes of the electric grid in order to operate reliably in 2040 consistent with the CLCPA goals. Also, as described above in the section titled *Revenues in the Future*, the NYISO will work to study various scenarios to understand the implications of the planned enhancements for creating incentives and improving revenues for resource flexibility.

## Conclusions and Key Takeaways

A rapid transition is underway in New York State from electric energy produced by central-station fossil fuel generation to renewable intermittent resources and distributed generation. The pace of this transition is driven primarily by state policy, notably New York's Climate Leadership and Community Protection Act (CLCPA). Technological advancements are expanding the capabilities of new resources and lowering their costs, further driving broader industry changes. In order to achieve the transformation anticipated, the NYISO, together with stakeholders, must provide the leadership to develop innovative products that allow wholesale markets to serve the reliability requirements of New Yorkers while maximizing efficiency through this transition.

The key element of this leadership is to anticipate the needs for existing and new grid reliability services and proactively evolve the wholesale market design to balance the electric system to achieve reliability. To maximize the benefits of the new types of resources expected, the NYISO will leverage its expertise in developing and operating best-in-class wholesale markets, to enhance its market structure that will facilitate the transition to a renewable resource base.

The NYISO is actively evaluating these anticipated needs in order to develop a plan to successfully meet these future challenges. We approach these questions with two guiding principles: (1) all aspects of grid reliability must be maintained; and (2) competitive markets should continue to maximize economic efficiency and minimize the cost of maintaining reliability while supporting the achievement of New York's climate policy codified in the CLCPA. Under these principles, competitive market prices serve as a powerful investment signal: they rise where and when necessary to attract and elicit essential grid services needed to maintain reliable electric service for consumers.

The energy and ancillary services design enhancements discussed above will provide appropriate pricing signals for generating resources that are responsive to real time changes in system conditions. An approach that emphasizes energy and ancillary services products and market pricing that are reflective of system conditions and operational requirements is important for incenting those needed attributes.

Steps also need to be taken to enhance the capacity market. It is important to improve the resource adequacy models used to set the Installed Reserve Margin and Locational Capacity Requirements and better align compensation with performance given the changing power grid.

The NYISO's existing capacity market BSM rules also require review in order to preserve competitive price signals and economically efficient market outcomes required to maintain system reliability and support the achievement of New York's climate policy codified in the CLCPA. To achieve this, the NYISO plans to engage with stakeholders to conduct a comprehensive review of the BSM rules aimed at modifying NYISO market structures in a balanced manner that support the transitioning grid.

Twenty years of wholesale markets in New York have provided substantial benefits to New Yorkers. The NYISO looks forward to engaging with policymakers and stakeholders to address the challenges and potential solutions identified in this report, which will play an important role in achieving the environmental objectives of the state while maximizing the benefits of wholesale markets to New York's energy consumers.

# Appendix A: The Existing Market Design

This appendix describes how each of the three markets work, and how they are priced, how they are designed to combine to provide revenue adequacy, and how these markets are complemented by planning and operations processes within the NYISO.

## Current Energy Market Design

Energy refers to the same "kWh" that customers consume as they operate their electrical appliances and equipment. NYISO operates a market for energy in two timeframes: in real-time, and day-ahead. In the real-time energy market, NYISO's RTD dispatches enough energy from the generation fleet to meet forecast demand for the next 5-minute interval. The RTD selects the lowest cost set of resources possible, based on their offers for incremental energy, considering unit operating limits (including ramp rates) and transmission constraints. Offers are subject to market power mitigation, through automated conduct and impact tests and potential reduction to reference levels that reflect short-run marginal cost to ensure efficient dispatch and competitive pricing. When clearing the market in each interval, the RTD calculates nodal prices based on the highest cost offers that are needed to fully meet forecast demand. Nodal prices are considered "uniform clearing prices" in that they are set by the marginal resources, and inframarginal resources will earn more than their incremental offers. This provides for some recovery of fixed costs. However, a key feature of NYISO's market is that competitive energy prices based on marginal short-run marginal costs may not provide needed resources full recovery of their fixed costs so that they are willing to stay online and/or invest. That shortfall (from energy plus ancillary services revenues) is addressed by the capacity market, as discussed below.

NYISO also runs a DAM through which most volume in the market transacts, but the DAM must be understood as a primarily financial market that helps prepare operations for the real-time market. The DAM enables market participants to hedge against RT prices; it helps generators plan their fuel procurement and commitment; and provides NYISO visibility into which generators will be used. In fact, the DAM is semi-physical in that non-quick start units that the market scheduling software clears are considered "committed" and are promised to be able to operate in a way that does not lose money, as discussed below. (Further commitments can be made for reliability reasons following the DAM, all the way up to the RTC occurring 15- to 30-minutes before the RTD, and quick start units that can start in 10-minutes may be started in RTD.)

In the DAM, demand reflects customers' and financial participants' bids for energy, which can be price-sensitive. Supply is represented by three-part offers of individual generators as well as import offers and virtual supply offers. Three-part generator offers include start-up costs, minimum generation costs (known in other areas as no-load costs), and incremental costs (combined with information on operating constraints, such as startup time, minimum run-time, and minimum/maximum capability when on) to allow the ISO to decide which units should turn on to minimize total costs in a multi-period optimization. NYISO runs the market to clear bids and offers and calculate hourly nodal and zonal clearing prices. Commitments in the DAM are financially binding, and load pays and generators get paid the DAM prices for those commitments. Deviations from the DAM commitments are settled at the RTM prices as discussed above.

DAM prices are naturally less volatile than RTM prices that fluctuate with unexpected changes in supply and demand. However, DAM and RTM prices are roughly equal on a longer average basis. Both are driven by fundamentals, especially natural gas prices and supply/demand tightness. Since 2010, energy prices across NYISO have trended downward as natural gas prices have fallen.[23] The marginal suppliers in most hours have been either natural gas generators or hydroelectric resources with storage whose offers reflect the price of natural gas.[24] Wind and solar are rarely marginal (less than 5% of intervals from 2015 – 2017), and have not yet had a significant effect on prices.[25] As wind and solar resources grow, they may become increasingly the marginal supply resources and put downward pressure on prices.

### Current Ancillary Services Market Design

NYISO administers two general categories of market-based ancillary services: regulation and operating reserves. The NYISO also procures some ancillary services through cost-of-service rates rather than markets. Grid services are not procured since they have been in plentiful supply and have been provided naturally as a byproduct of traditional generation.

#### Regulation Service

Electrical systems need “regulation” to balance supply and demand and maintain frequency within a 5-minute dispatch interval. The need arises primarily from very short term fluctuations around the interval-to-interval load trend, but regulation can also help address sudden disturbances while that underlying “contingency” services are ramping up. Regulation is provided by resources that are able to respond to base point signals to move up and down every six seconds. It is procured as a “reserve” since providing regulation means reserving some operating capacity to be able to ramp up (and operating above the minimum operating point to be able to ramp down). The market software identifies and assigns the lowest cost providers of such reserves for each five-minute interval as part of its real-time energy and ancillary

23 See Potomac Economics (2018), p. 3.

24 Offers from hydroelectric resources with storage reflect the opportunity cost of foregone sales in other hours in which gas is marginal

25 See Potomac Economics (2018), p. 6.

services co-optimization. The regulation price reflects the shadow price of meeting the regulation constraint, so it fully compensates providers for their opportunity cost of not providing energy or other ancillary services, and is comprised of a capacity and movement portion. Providers are paid the regulation capacity price for the 5-minute regulation schedule plus the regulation movement price for any net MWh it is dispatched to provide (ups plus downs) over that interval.

The amount of regulation NYISO procures varies hourly and seasonally based on system conditions, but is usually in the range of 150 to 300 MW. Most regulation is provided by hydroelectric resources, and some is provided by combined-cycle plants. In 2016 and 2017, the average price for regulation was $9.30/MWh; [26] total payouts for regulation in 2016 were $23.5 million. This has been sufficient to meet NYISO's needs because plenty of regulation-capable resources are online and the price pays for their costs to provide regulation service. Regulation prices rose between 2016 and 2017. This price increase was driven by lower loads in 2017; lower loads mean committing fewer resources, reducing the available supply of regulation (and 10-minute spinning reserve) resources.[27] This trend may continue if growth in wind and solar generation results in lower commitment of traditional regulation resources.

#### Operating Reserves

To reliably operate electric systems within acceptable criteria, NYISO must always be prepared to restore supply-demand balance following a potential sudden loss of a generator or transmission used to access generation.[28] This is done by being ready to deploy a matching amount of very fast-responding 10-minute reserves; then to be able to replace them with medium-fast-responding 30-minute reserves so that they system is prepared for the next possible contingency. Total operating reserves must be greater than or equal to two times the largest single supply contingency (in MW) as defined by the NYISO. Of that, total 10-minute reserve must be greater than or equal to the largest single supply contingency (in MW) as defined by the NYISO. Of that, 10-minute spinning reserve must be greater than or equal to one-half of the largest single contingency (in MW), as opposed to non-synchronized reserves. These reserves are subject to various locational requirements to account for transmission constraints, as described in NYISO's Ancillary Services manual.[29] These are illustrated in Figure 10.

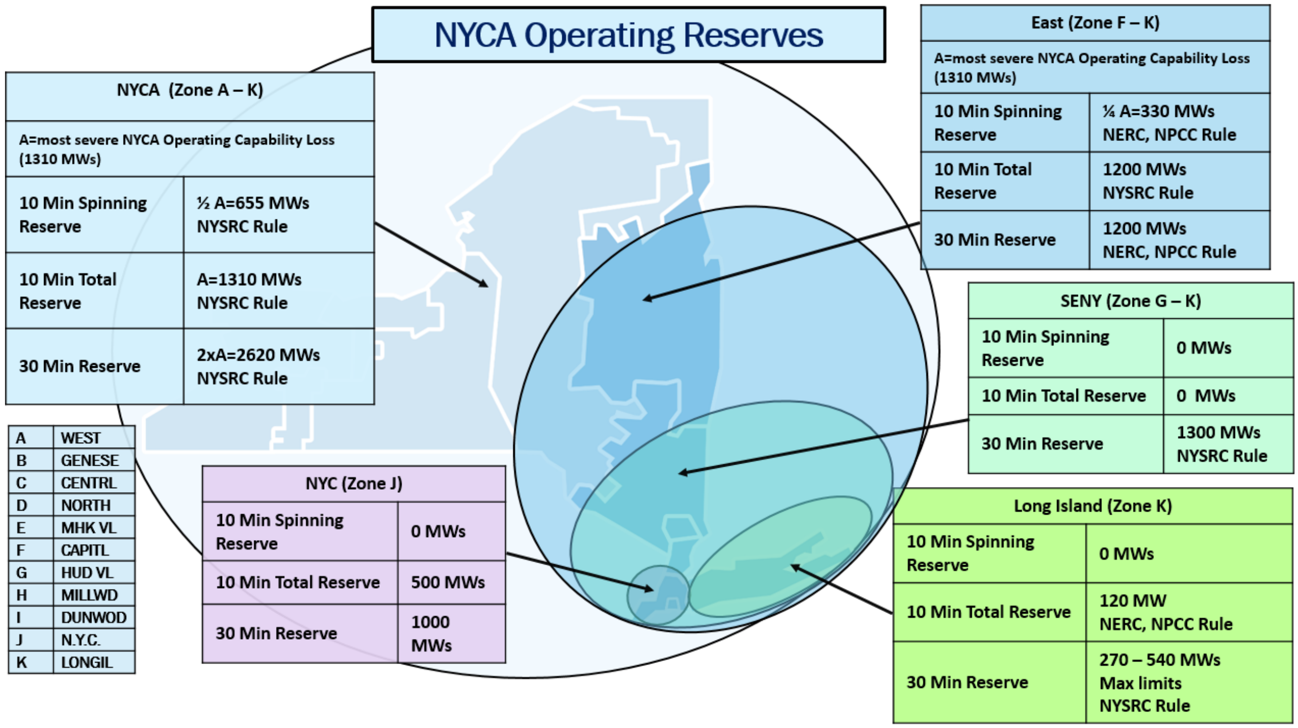
26 See Potomac Economics (2018), p. A-16.

27 See Potomac Economics (2018), p. A-16.

28 The most immediate response to contingencies includes inertia and primary frequency response, as discussed below; and some use of regulation as noted above. It is the job of the contingency services to fully compensate for the contingency and restore supply-demand balance and system frequency within 10 minutes.

29 See NYISO (2018b), pp. 41 and 80.

**Figure 10: NYCA Operating Reserve Requirements and Locations**




These operating reserve requirements are met through the ancillary services markets administered by NYISO's market scheduling software. The scheduling software expresses the requirements as "demand" for reserves, and it dispatches energy and holds reserves from the most cost-efficient combination of resources available (after having ensured day-ahead and hours-ahead that there is enough capacity committed). The market clearing price of each reserve in each interval is set by the highest offer (given by the energy opportunity cost calculated within the optimization) taken to meet demand. In the event of a shortage, an operating reserve demand curve (Demand Curve) will establish the price (and is likely translated to the energy price and other substitutable ancillary services through the co-optimization). The Demand Curves and other key elements of each reserve type are summarized below in descending order of value and price. Note that the Demand Curves can be additive in price formation: since co-optimization recognizes that higher value products could be substituted for lower value ones, a shortage of the lower value products increases the price of not only that product but the higher value ones as well. Similarly, Demand Curve shortage prices add to the energy clearing price to the extent that the marginal energy providers could alternatively be providing any of the scarce reserves.

**Table 5: NYISO Current Reserve Products**

| Reserve Type | Qualification Requirement | Commonly Provided By | NYCA Demand Curve Price ($/MWh)30 |
|---|---|---|---|
| 10-Minute Spinning Reserves | Supply resources already synchronized to the system that can respond to instructions from the NYISO to change output level within 10-minutes | Online dispatchable generators | $775 |
| 10-Minute Non-Synchronized Reserves | Supply resources that can be started, synchronized, and loaded within 10-minutes | Jet Engine type gas turbines | $750 |
| 30-Minute Reserves | 30-Minute Spinning Reserves<br>Supply resources already synchronized to the system that can respond to instructions from the NYISO to change output level within 30-minutes.<br>30-Minute Non-Synchronized Reserves<br>Supply resources that can be started, synchronized, and loaded within 30-minutes. | Online generators<br><br>Combustion turbines | $25 - $750 (varies with degree of shortage and location) |

Source: NYISO (2018d).

In 2016 and 2017, NYISO day-ahead prices for operating reserves were quite similar across products: 10-minute spinning reserve prices were $5.21-$5.63/MWh across West NY, Capital, and Southeast NY regions in 2016 and $4.55-$5.00/MWh in 2017, 10-minute non-synchronized reserve prices were $5.12-5.38/MWh across regions in 2016 and $4.01-4.18/MWh in 2017, and 30-minute operating reserve prices were $5.12/MWh across all regions in 2016 and $4.01/MWh in 2017.[31] Prices fell from 2016 to 2017 despite an increase in energy prices in most areas due to lower offer prices.[32] 30-minute reserves accounted for a substantial majority of day-ahead reserve costs.

#### Cost-Based Services Procured

Reactive Supply and Voltage Support Service (Voltage Support) and black start capability service. Voltage Support and Reactive Power can be thought of as providing the pressure that moves real power, or the power that people consume, through the transmission system. Reactive power must be located

30 Other reserve regions have their own demand curves, see NYISO (2018b), p. 80.

31 See Potomac Economics (2018), p. 11, Figure 3.

32 The IMM has reported difficulties in accurately estimating the marginal cost of providing reserves. The IMM suggest that a possible reason for lower offer prices was that suppliers gained more experience with market changes associated with the implementation of the Comprehensive Shortage Pricing Project in November 2015.

throughout different parts of the power system allowing for transfers of lower cost energy from locations far from large load centers to the areas where most power is being consumed. In the context of the New York power system reactive power is needed to move power from the hydroelectric projects near the Niagara Falls in Western New York and into the large load centers of New York City and Long Island. The NYISO pays suppliers for their demonstrated reactive supply capability based on a cost of service based rate.

Separately, the NYISO procures black start capability service. Black start capability represents the key Generators that, following a system-wide blackout, can start without the availability of an outside electric supply and are available to participate in system restoration activities that are under the control of the NYISO or, in some cases, under local Transmission Owner Control. If a partial or system-wide blackout occurs, these units assist in the restoration of the New York Control Area (NYCA). Specific generating units, identified in the NYISO Restoration Plan or, in specific Transmission Owners' local restoration plan(s), have the capability and training required to start up without the presence of a synchronized grid to provide the necessary auxiliary station power. The NYISO pays selected suppliers for their demonstrated black start capability based on a cost of service based rate.

#### Unpaid Services

NYISO implicitly uses other grid services that it does not pay for at all because they have historically been provided naturally and plentifully as a byproduct of traditional generation. These include inertia, and primary frequency response.

- **Inertia** refers to the spinning mass in the entire Eastern Interconnection, spinning at the system frequency 60Hz, which naturally maintain supply-demand balance immediately following a contingency by slowing down and converting rotational kinetic energy into electrical energy. This causes frequency to fall (although very slowly in the Eastern Interconnect). There is plenty of inertia because the Eastern Interconnect is so large with so many synchronous generators.
- **Primary frequency response** refers to generators with governor controls which automatically inject more fuel or steam into their turbines to quickly increase their output to arrest the frequency drop before contingency reserves fully ramp up (within 10-minutes) to restore frequency. The NYISO currently has approximately twice the primary frequency response required by NERC.

## Current Capacity Market Design

NYISO has administers the ICAP market as the supplemental mechanism to energy and ancillary services revenue to ensure resource adequacy to meet mandated reliability standards.[33] While the market rules have shifted over time, the fundamental design of the capacity market is largely unchanged. The NYISO administers seasonal, monthly, and spot ICAP auctions one month out. The seasonal and monthly markets match locational bids to buy and offers to sell, whereas the spot market has a downward sloping capacity demand curves for each of four capacity zones. These demand curves reflect NYISO's forecast of capacity needs and zonal new entrant costs. Supply resources then compete by submitting capacity offers reflecting their net going forward costs, and NYISO clears the lowest-cost combination of resources that achieves the capacity requirement.[34] Cleared resources are obligated to offer into the energy market. To the extent they have outages or derates, they are subject to having the amount of capacity they can offer in future auctions reduced.

In the three most recent capability years, annual average spot prices have ranged from $1.30-2.39/kW-month in NYCA, $2.55-3.70 in Long Island, $6.79-10.68 in New York City, and $6.17-6.69 in the G-J Locality. Prices are driven by supply/demand fundamentals, such as peak demand, net import levels from external control areas, and resource entry and exit, as well as by capacity market design parameters, such as the minimum locational ICAP requirements (LCRs) and demand curve reference points. Prices tend to be lower in Winter Capability Periods than in Summer Capability Periods, due to additional capability of some resources to produce electricity. Recently, lower peak demand and changes in LCRs were responsible for most of the year-over-year capacity price changes.[35]

## Current Planning and Operations Processes

To facilitate investment in new and upgraded transmission, the NYISO's planning processes provide independent and authoritative information to investors, stakeholders, and policymakers. These planning processes are designed to support the reliability and efficiency of the electric grid and the ability of the electric grid to support public policy goals.

### NYISO's Planning Processes

- Long-term reliability planning processes, including the Comprehensive Reliability Plan and the Reliability Needs Assessment

33 Most US areas set reliability metrics according to the "1-in-10" standard, i.e., a probability-weighted average of 0.1 loss-of-load events per year. NPCC and NYSRC have promulgated reliability standards more stringent than those developed by the North American Electric Reliability Corporation (NERC). NYISO reliability standards are described further at: NYISO (2019g).

34 In addition, NYISO has defined reliability backstop mechanisms for transmission owners to address implement supply or transmission solutions not resolved through NYISO's competitive ICAP market, but such backstops have been used sparingly to date.

35 See Potomac Economics (2016), (2017), and (2018).

- Interregional planning that coordinates system planning across neighboring regions to evaluate how changing system conditions within and across our regions influence system needs
- Resource interconnection processes designed to ensure that new resources effectively interconnect to the grid while maintaining bulk power system reliability and efficiency
- Generator deactivation planning that identifies potential reliability impacts resulting from the deactivation of existing supply resources
- Economic planning processes that evaluate and identify opportunities for economic transmission investment
- Public policy transmission planning processes that address transmission needs driven by federal and state public policies

The NYISO's planning studies use sophisticated models to assess the capability of the transmission system and the adequacy of resources to meet New York's electric needs. There are numerous factors included in these models to determine system needs, including:

- The impact of changes in generation and transmission resources available to the electric system
- Forecasts of consumer demand and peak loads
- Economic outlook data
- Weather models
- The impact of demand response resources that are paid to reduce energy usage at peak times

#### Reliability Planning Process Comprehensive Reliability Plan and Reliability Needs Assessment

The NYISO's 2018 Reliability Needs Assessment (RNA) evaluated expected supply resources, demand levels, and transmission capability of New York's bulk power system for the study period 2019 through 2028. The NYISO develops the RNA in conjunction with market participants as the first step in the NYISO's 2018-2019 Reliability Planning Process. The RNA is conducted every two years and serves as the foundational study used in the development of the NYISO Comprehensive Reliability Plan (CRP). Each RNA is performed to evaluate electric system reliability for both resource adequacy and transmission security over a 10-year study period. If the RNA identifies any violation of reliability criteria for the bulk power system in New York State, the NYISO issues a report which quantifies the amount of megawatts of capacity and the needed location of that capacity necessary to resolve the identified reliability need.

Leveraging the power of competition and seeking to minimize ratepayer costs, the NYISO responds to the identification of reliability needs by soliciting market-based solutions, which may entail investment in transmission, new supply resources, or demand reduction measures. To assure that solutions are available where and when needed, the NYISO also designates one or more responsible transmission owners to develop regulated backstop solutions to address each identified reliability need, while other developers can also provide alternative regulated solutions. Although conducted by the NYISO's planning staff, the RNA is the result of significant stakeholder engagement, culminating in approval by stakeholders in the shared governance process, and final approval by the NYISO's independent Board of Directors.

Following the issuance of the RNA, the CRP details the NYISO's plans for continued reliability of the bulk power system over the 10-year planning horizon. The CRP also updates assumptions critical to determining system needs and evaluates solutions proposed to resolve identified reliability needs found in the RNA. Market-based solutions developed in response to market forces are favored over regulated solutions to reliability needs. If the market does not adequately respond to an identified need, reliability will be maintained by either regulated backstop solutions developed by the transmission owners, which are obligated to provide reliable service to their customers, or alternative regulated solutions developed by other developers.

#### Planning Transmission Infrastructure for Public Policy Requirements

Under the NYISO's public policy transmission planning process, interested entities propose, and the PSC identifies, transmission needs driven by public policy requirements. A public policy requirement is defined in the tariff as a federal or state law or regulation, including a PSC rulemaking order, which drives the need for additional transmission capability in the state.

In response to a declared public policy need, the NYISO requests that interested entities submit proposed solutions and evaluates the viability and sufficiency of those proposed solutions to satisfy each identified need. The NYISO then ranks the solutions and may select the more efficient or cost-effective transmission solution to each identified need. The NYISO issues its findings through a Public Policy Transmission Planning Report, which is reviewed by NYISO stakeholders and approved by the Board of Directors.

#### Interregional Planning

Under FERC Order No. 1000, and in collaboration with its New England (ISO-NE) and Mid-Atlantic (PJM) neighbors, the NYISO expanded its interregional planning process based upon the existing Northeastern ISO/RTO Planning Coordination Protocol that had been in place for more than a decade. In May 2018, the three ISO/RTOs issued the 2017 Northeast Coordinated System Plan, which did not identify a need for new interregional transmission projects at that time.

As a member of the Eastern Interconnection Planning Collaborative (EIPC), the NYISO also conducts joint evaluations with planning authorities across the entire Eastern Interconnection, a region that includes 40 states and several Canadian provinces from the Rocky Mountains to the Atlantic Ocean, and from Canada south to the Gulf of Mexico. The NYISO was a leader in the formation of the EIPC, which involves 20 electric system planning authorities, and was created in 2009 as the first organization to conduct interconnection-wide planning analysis across the eastern portion of North America.

Among its efforts, the EIPC conducted studies assessing a range of possible energy futures which found the reliability plans of electric system planners in the Eastern Interconnection integrated well to meet potential reliability needs.

In October 2018, the EIPC issued the State of the Eastern Interconnection Report that summarizes the work completed by the EIPC since its inception in 2009. Specific topics include reports that combine the individual plans of each of the major planning coordinators in the Eastern Interconnection and verify that that the individual plans work together to maintain bulk power system reliability throughout the interconnection. These reports are also used to analyze various future scenarios of interest to policymakers and other stakeholders. They also extend the collaborative activities started under a U.S. Department of Energy grant in 2010 to study the Eastern Interconnection transmission system under a wide variety of future scenarios and resource mixes.

The State of the Eastern Interconnection Report concludes that the individual power systems in the Eastern Interconnection are being planned in a coordinated manner. Studies completed by the EIPC demonstrate that the respective transmission planning and interconnection processes have yielded transmission plans that are well coordinated on a regional and interconnection-wide basis. EIPC studies also show that planning coordinators' regional transmission plans, including generator retirements and additions, will require continued study enhanced by broader interconnection-wide coordination to ensure that individual regional plans do not conflict with other regional plans.

#### Economic Planning Congestion Assessment and Resource Integration Study (CARIS)

The NYISO evaluates congestion on the New York bulk power system as part of its planning processes with its biennial Congestion Assessment and Resource Integration Study (CARIS). The study is an economic analysis of transmission congestion on the New York bulk power system and the potential costs and benefits of relieving transmission congestion. Solutions to congestion may include:

- Building or upgrading transmission lines and related facilities
    - Building generation within constrained areas
    - Employing measures to reduce annual energy consumption for electricity in the congested locales
- Employing measures to reduce peak demand for electricity in the congested locales

The CARIS process analyzes generic transmission, generation, energy efficiency, and demand response solutions in regions that could ultimately yield congestion cost savings for power consumers. The 2017

CARIS study published in April 2018 identified the most congested parts of the New York State bulk power system based upon historical data (2012-2016) as well as estimates of future congestion (2017-2026).

The CARIS study shows the most congested areas of the transmission system are associated with the Central East Interface that runs between Utica and Albany. The study also shows increasing congestion towards the downstate load areas and that system production cost savings would be realized by relieving constraints between Central East and the lower Hudson Valley. These findings reinforce many prior studies demonstrating the benefits of relieving transmission constraints between upstate and downstate New York. By relieving these constraints, energy from existing upstate resources would economically flow to where it is needed downstate. It would also support the development of new renewable sources of power upstate and greater use of renewable energy resources from Canada.

#### Merchant/Class Year Transmission Proposals

Several merchant plans for transmission have emerged and are in various stages of development. Merchant transmission projects are not necessarily associated with transmission projects driven by reliability, public policy, or CARIS-like needs for transmission expansion. Merchant transmission investment, much like merchant supplier investment, seeks to put private capital to work to expand bulk power system capability. Rather than regulated rates of return, revenue for these transmission projects is driven by the grid's use of these merchant facilities.

The NYISO interconnection queue includes several merchant transmission projects in varying stages of development. Like proposed generation projects in the NYISO's interconnection queue, inclusion in the queue and the completion of various stages of the interconnection studies does not indicate that individual facilities will be completed and enter into service. However, the interconnection queue includes more than 7,500 MW of additional transmission capacity within the state, including projects that seek to expand capability from upstate New York and Canada to downstate New York and projects seeking to export power to neighboring regions.

These transmission proposals are in addition to those being developed under the NYISO's Public Policy Planning Process described above.

# Appendix B: Reliability Gap Analysis

**NYISO Reliability Gap Assessment**

**Scott Harvey and NYISO Staff [36]**

This white paper identifies a number of areas of potential future reliability gaps assuming a high level of intermittent resources operating in New York Independent System Operator (NYISO) and outlines recommendations to address these gaps.

The potential areas of future reliability gaps assuming a high level of Intermittent and/or limited energy supply resources are expected to include:

1. Maintain Ability to Balance Load and Generation
2. Maintain Ten-Minute Operating Reserves
3. Maintain Total Thirty-Minute Operating Reserves
4. Maintain Ability to Meet Daily Energy Requirements
5. Maintain Reliable Transmission Operations
6. Maintain Black start Capability
7. Maintain Voltage Support Capability
8. Maintain Frequency Response Capability
9. Maintain Resource Adequacy
10. Ability to Manage Supply Resource Outage Schedules

## 1. Maintain Ability to Balance Load and Generation

Potential Reliability Gap # 1: The NYISO may be challenged to meet NERC control performance requirements balancing high levels of intermittent generation with system demand that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 1: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Increasing statewide regulation procurement requirements
b. Investigate benefits of separate regulation “up” and “down” service
c. Increasing statewide ten and/or thirty-minute operating reserve requirements
d. Investigating the need for ramping requirements in NYISO markets
e. Improving the NYISO’s Real-Time Energy Market Dispatch
f. Accounting for increased real-time load forecast uncertainty

36 Scott Harvey is a consultant with FTI consulting. He has also been a member of the California ISO Market Surveillance Committee since April 2011, and has worked with NYISO, MISO and the Ontario IESO on issues relating to market design and managing transmission system reliability on transmission systems meeting load with high levels of intermittent resource output.

g. Promoting more frequent interchange scheduling with neighboring regions

**Background:**

The following sections focus on forecasting and scheduling issues that will also impact the ability of the NYISO to balance load and generation with a resource mix that includes much more intermittent resource output than today.

It is generally recognized today that meeting New York load with high levels of intermittent resource output, particularly solar and wind generation, will require the NYISO to have sufficient flexible, dispatchable and potentially fast ramping supply to balance variations in intermittent resource output. These variations will include not only short-term variations in output during the operating day as a result of changes in wind speed and cloud cover but also a sustained ramp up of solar output at the beginning of the day as the sun rises and a sustained ramp down of solar output at the end of the day as the sun sets.

This potential reliability gap concerns the ability of the NYISO to balance load and generation within the time frame of the real-time dispatch and regulation markets with a resource and output mix that includes much more intermittent resource output than today. NERC tends to view this issue as simply a matter of the availability of resources able to provide load balancing. The challenges the California ISO has encountered in balancing load and generation show that the issues the NYISO will need to address as its resource mix changes will be more complex than this, involving not only the amount of flexible generation available to balance load and generation but also the ability of the balancing software, particularly RTD, to recognize the need to balance load and generation in the appropriate time frame and potentially changes in the way regulation instructions are determined by AGC.[37]

The availability of sufficient ramp capability to balance variations in intermittent resource output will need to be addressed in five time frames. These are the time frame of the regulation balancing instruction, the time frame of the real-time dispatch, the time frame of the intra-day unit commitment decisions, the time frame of the day-ahead market, and the time frame in which investments in resources able to provide balancing will be made. The NYISO's current processes have both strengths and limitations in each of these times frames. Some of these limitations can likely be addressed with minor refinements of existing reliability processes and tools, but addressing others may require more fundamental changes in the current processes and tools.

37 The challenges the California ISO has encountered in balancing load and generation as the level of intermittent resource output has risen over the past few years are discussed in a wide variety of documents. We think the following provide helpful context for understanding the challenges the New York ISO will need to address California ISO, Market Performance and Planning Forum, December 7, 2016 pp. 17-23; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55, California ISO, Final Flexible Capacity Needs Assessment for 2019, May 21, 2018; and discussion in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 22-37.

If the NYISO develops methods that will allow it to effectively dispatch resources to balance net load this will address the concerns NERC focused on with whether there will be enough resources on line to balance these variations in net load. A key complication that comes up in the context of this issue, and under several additional topics below, is the likely low level of energy prices during times when intermittent resource output is high, which will make it very expensive to keep thermal generation on line generating power at their minimum load output to provide upward ramp capability. Similarly, low or negative energy prices would also make it very expensive to rely on thermal or hydro resources to provide down regulation (because the resources would need to be scheduled at an output above minimum load in order to be able to regulate down). These expected future market conditions will tend to make it desirable to shift to separate up and down regulation products, at least during the hours of high intermittent resource output. In addition, potential future changes to market rules to allow solar and wind to provide down regulation may help reduce the cost of regulation while meeting the reliability needs to balance generation and load.

a. Increasing NYISO Regulation Procurement Requirements

Regulation (e.g. the capability of generation to respond to six second dispatch instructions through Automatic Generation Control (AGC)) plays a secondary role in balancing load and generation for the NYISO today. One of the challenges facing the NYISO as its resource mix evolves is whether regulation can continue to play this secondary role, with most of the variations in net load balanced by the real-time energy dispatch, or if the NYISO will need to make fundamental changes in its design reflecting a greater reliance on regulation.

As the level of intermittent resource output has increased, the California ISO has encountered increasing difficulty in balancing variations in intermittent resource output with its real-time dispatch. This difficulty in using the California ISO's economic dispatch to balance variations in intermittent resource output has been due in part to net load forecast latency which is discussed below. When variations in intermittent resource output cannot be balanced in the economic dispatch, this has resulted in an increased reliance on regulation to balance generation and load, potentially requiring that greater amounts of regulating capability be scheduled.[38]

The NYISO will need to be prepared to address similar challenges in balancing load and generation within the five minute time frame of the dispatch interval as the level of intermittent generation in New York rises. One option for addressing net load balance variations could be through a substantial increase in

38 See California ISO, Market Performance and Planning Forum, December 7, 2016 pp. 17-23; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55.

the amount of regulation capability that would be scheduled and available for real-time operations. Such an approach would need to address a number of complicating factors. Not only would substantial regulating capacity be needed to balance net load if RTD is unable to consistently carry out this function, but the inability to rely on the dispatch of generation to restore regulation would mean that the regulating resources would need to have sufficient energy and dispatch range to meet sustained net load imbalances. In addition, the commitment of thermal resources to provide additional regulation capability would increase the amount of emitting generation operating at minimum load.

Moreover, the reliance on much larger amounts of regulation capability to balance load and generation would greatly diminish the value of real-time time prices in incenting performance and raise issues with the current design of the regulation balancing function. If an increased level of generation, storage and/or regulating load were used to provide regulation capability, then the NYISO would need to evaluate whether changes would be needed in the deployment of regulation to take account of congestion impacts, to minimize the cost of meeting load, and to maintain sufficient regulation capability (i.e.to avoid drawing down energy or capacity limited regulation resources) above what is currently done by AGC today.

Low energy prices during periods when intermittent resource output is on the margin will also make it more expensive to provide regulation from thermal resources. These cost changes could be addressed with a shift to separate up and down regulation products, so that thermal resources would not have to be dispatched up above minimum load in order to provide regulation down, which could instead be provided by intermittent resources that could reduce output, and a shift to non-generation resources for regulation, either batteries or controllable demand.

It is possible that as the reliance on regulation to balance net load and generation increases in the Northeast region, the NYISO, Ontario Independent Electricity System Operator (Ontario IESO) and ISO–NE could make greater use of the existing framework for taking account Area Control Error (ACE) diversity within the region, (ACE Diversity Interchange)[39]. The potential gains from taking account of ACE diversity will be limited by the extent of transmission constraints within and between the ISOs, which appears to be the current impediment to use of the existing program. The current challenges entailed in taking advantage of ACE diversity within the region while managing transmission constraints could however become even greater with larger differences between actual and forecasted net load that need to be balanced with regulation.

b. Increasing statewide ten-minute spin and/or thirty operating reserve requirements

39 See NPCC, Regional Reliability Reference Directory # 5 Reserve, Section 5.11 ACE Diversity Interchange, October 11, 2012.

The key time frame for balancing variations in intermittent resource output is the real-time dispatch. It will be important to have enough resources on line or able to come on line quickly both the balance unpredictable variations in intermittent resource output and to balance large mostly predictable changes in intermittent resource output, such as the morning and evening solar ramp.

The MISO and California ISO moved forward in 2016 with implementation of ramp capability dispatch designs in an effort to maintain their ability to balance load and generation with rising levels of intermittent resource output. As is discussed below, these designs are still works in progress in both the California ISO and MISO. While there are lessons to be learned from the MISO and California ISO implementations, there is not yet a clear design in operation that the NYISO should emulate.

On the other hand, the first step towards a ramp capability product in the MISO was an increase in the spinning reserve requirement above the NERC minimum, followed by the introduction on May 1, 2012 of a lower shortage price for the dispatch of capacity scheduled to provide spinning reserves.[40] The recently proposed PJM ORDC would similarly increase the reserves cleared in the market in the hope that this would make more dispatch capacity and ramp capability available to balance real-time variations in intermittent resource output. Like the changes in the MISO spinning reserve target, PJM does not propose that the target quantities be set taking into account the potential for variations in net load during those specific system conditions nor take account of locational transmission constraints that might impact the dispatch of the generation providing the additional reserves.[41]

In a similar manner, the NYISO could utilize an increased ten-minute spinning operating reserve requirements that would be simultaneously optimized in real-time with much lower penalty prices than those currently applied to spinning reserves to provide for additional dispatch capability and that increased total ten and thirty-minute operating reserve requirements will allow for that on-dispatch capability to be maintained throughout the day. The exact proportion of increases in ten-minute spin, ten-minute total, and thirty-minute operating reserves would need to be studied so that the most effective and efficient use is made of available supply resources to meet real-time load.

c. Investigating the Need for NYISO Ramping Requirements

The MISO and California ISO have developed the ramp capability dispatch concept for use as a tool to help balance both predictable and unpredictable variations in intermittent resource output.[42] These

40 See MISO March 1, 2012 filing in FERC Docket ER12-1185, the discussion in Potomac Economics, 2012 State of the Market Report for MISO Electricity Markets, June 2013 p. 31 and 2015 State of the Market Report for MISO Electricity markets, Analytical Appendix, p. A-56.

41 See PJM March 29, 2019 filing in FERC Docket ER19-1486

42 The real-time dispatch of the California ISO, like the New York ISO, is based on a multi-interval optimization design that looks out an hour. This also helps the California ISO balance predictable variations in net load.

designs in effect commit and dispatch resources in real-time so as to make additional spinning reserves available for use in future intervals to balance variations in intermittent resource output.

These designs differ from a simple increase in the spinning reserve requirements in five important respects.

1. The capacity providing ramp capability is dispatched for energy at a much lower shadow price than the shortage price typically used for spinning reserves.
2. The ideal amount of additional ramp capability depends on the magnitude of the potential variations in intermittent resource output, given system conditions at that time of day, rather than on the size of potential generation or transmission contingencies typically used to establish spinning reserve requirements.
3. The locational requirements for these reserves need to reflect the constraint patterns impacting the balancing of intermittent resource output rather than those associated with a large generation or transmission contingency.
4. The energy market cost of resources providing ramp capability would ideally be taken into account in scheduling additional ramp capability, as resources scheduled to provide ramp capability would be dispatched for energy much more often than spinning reserves will be activated following contingencies.
5. The ramp capability designs not only attempt to provide additional ramp capability to balance large decreases in intermittent resource output, they also attempt to provide downward ramp capability to accommodate large increases in intermittent resource output at lower cost, and with fewer curtailments.

Each of these elements is discussed further below.

#### Shortage price

The current NYISO shortage price for spinning reserves is $775. If this shortage price were applied to an increased spinning reserve requirement, the ramp capability used to meet the increased spinning reserve requirement would not be available to balance load and generation unless energy prices exceeded $775. With a ramp dispatch design, the goal is to maintain additional ramp capability when its cost (shadow price) is low, and to use this ramp capability to balance load and generation when the cost savings from using the ramp capability in the current dispatch interval is high. Hence the MISO uses a penalty price of $5 for reductions in ramp capability below the target level and the California ISO uses a demand curve for reductions in ramp capability with values ranging from near 0 (when there is a large amount of ramp capability available relative to the target) to $247 (when there is relatively little available).[43]

43 These penalty prices are discussed further in in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 97-99.

#### Reserve Quantity

The MISO ramp dispatch implementation targets having enough ramp capability to meet predicted ramp needs (the forecast change in net load) plus a margin for net load forecast uncertainty.[44] The current MISO design uses the same target quantity for ramp capability to meet net load forecast uncertainty over the day.[45] The California ISO, which has a much higher level of both behind the meter and wholesale energy market solar generation than the MISO, has attempted to implement a design in which the ramp capability target to cover net load forecast uncertainty varies from hour to hour and is continuously updated based on system conditions.[46] Our review of the performance of the MISO and California ISO implementations of ramp capability dispatch designs leads to the conclusion that in markets with high levels of intermittent resource output the setting of the ramp capability target will need to evolve to designs in which the ramp capability target takes account of the current level of intermittent resource output, a high target when intermittent resource output is expected to be high (and hence could fall by a lot) and a lower target when intermittent resource output is expected to be low (and hence can't fall much lower).

#### Locational Requirements

NYISO locational reserve requirements are based on assessment of generation and transmission outage contingencies. There is no assurance that these locational definitions will be appropriate for balancing large future variations in intermittent resource output on the NYISO transmission grid. A critical weakness in the initial implementations of the ramp capability dispatch in both MISO and the California ISO has been the failure to take sufficient account of the impact of transmission constraints on the dispatch of generation scheduled to provide ramp capability.[47]

#### Energy Market Cost

The NYISO's scheduling of spinning reserves does not take account of the energy offers associated with

---

44 The MISO uses a single interval dispatch, so absent modeling future ramp needs through the ramp capability dispatch design, the dispatch for the current interval would not take account of predictable ramp needs in future intervals. The New York ISO, like the California ISO and Ontario IESO, utilizes a multi-interval optimization design for its real-time dispatch so its base dispatch takes account of predictable ramp needs in future intervals. Unlike the California ISO, however, the New York ISO real-time dispatch does not model each future dispatch interval in 5-minute increments but models them in a combination of 5, 10 and 15-minute increments that can lead to blind spots in the identification of predictable ramp needs in future intervals.

45 See the discussion in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018. Pp 87-92. Our initial scoping/cost benefit analysis of the ramp capability dispatch for MISO used targets that varied in a few broad hourly blocks over the hours of the day. See MISO, Stakeholder 5th Technical Workshop, Ramp Capability in MISO Markets, April 14, 2012 pp. 49-50.

46 This is discussed in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 74-87. This paper contains references to the relevant California ISO documents.

47 This is discussed in Joe Cavicchi, Scott M. Harvey, "Ramp Capability Dispatch and Uncertain Intermittent Resource Output," Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp. 92-97.

the capacity providing reserves. This is a reasonable design because spinning reserves are rarely dispatched out of market in response to contingencies. This is not the case for generation capacity providing ramp capability. This capacity may be dispatched for energy a significant percentage of the time it is scheduled, and part of reasons for scheduling this capacity is to avoid the need to dispatch very high cost resources to balance variations in intermittent resource output. This goal may not be achieved if the scheduling process does not take some account of the energy cost of the resources scheduled to provide ramp capability.

#### Downward ramp capability

Unlike spinning reserves, ramp capability dispatch designs maintain the availability of both downward and upward ramp capability.[48] Balancing either predictable or unpredictable increases in intermittent resource output is less challenging than balancing reductions in intermittent resource output because increases in intermittent resource output can in principle be balanced by dispatching down intermittent resource output to manage transmission constraints and to avoid over generation until other supply resources can be ramped down. The NYISO was one of the first ISOs to introduce the economic dispatch of intermittent (wind) resource output and this design has since been implemented in most other ISOs. This design has proved reasonably effective in balancing load and generation when intermittent generation increases rapidly. While California ISO operators had concerns with their ability to dispatch down intermittent resource output a few years ago, those concerns have been relieved over the past few years by the level of intermittent resources participating in the California ISO dispatch.[49]

This ability to balance increases in intermittent output, however, depends on both intermittent resources and flexible resources participating in the economic dispatch rather than submitting inflexible price taking offers.

Analysis of transmission constraint patterns during high ramping hours will be important in order for the NYISO to avoid outcomes in which ramp capability is counted as available in assessing system conditions and committing generation but cannot be dispatched to balance variations in intermittent resource output because of transmission constraints. Analysis of the temporal pattern of ramp capability use is needed to avoid incurring the cost of maintaining incremental ramp capability in hours in which the

48 It is particularly important for the scheduling, and compensation, of downward ramp capability to take account of the offer price of downward ramp capability. Output that can be dispatched down at extremely negative prices provides little value to power consumers in balancing variations in intermittent resource output.

49 It is still the case that only a subset of intermittent resources participate in the California ISO's real-time dispatch but the level of participation has been sufficient to allow the California ISO to balance rapid increases in intermittent resource output within the real-time dispatch. Instances of downward power balance violations have remained low for more than 2 years, see California ISO, Market Performance and Planning Forum, July 10, 2019 p.33. This low level of downward power balance violations over the past couple of years may in part reflect hydro conditions in California, which is an issue the California ISO must manage but the New York ISO does not face to a material extent.

probability of the additional ramp capability being needed is low (and hence the benefit from maintaining additional ramp capability low relative to this cost).

The NYISO should continue to track the ongoing refinements to ramp capability dispatch designs in MISO and California ISO and assess whether such a design should be implemented in New York in a manner that would help balance variations in intermittent resource output. In addition, the NYISO should undertake ongoing analysis of the locational and temporal patterns associated with significant variations in intermittent resource output in the NYISO. This information will be a critical element of any ramp capability design that may be implemented in the NYISO and this information will likely help inform other changes in NYISO operating practices or markets that would help more efficiently and reliably accommodate higher levels of intermittent resource output . A good understanding of likely transmission constraint patterns during high ramp hours will be beneficial to the NYISO in balancing generation and load whether the NYISO implements a ramp capability dispatch similar to California ISO or MISO or develops a different approach. Similarly, the ability to predict periods of high variability in net load will be beneficial to the NYISO whether or not it implements a ramp capability dispatch similar to the California ISO or MISO. Moreover, the ability to account for transmission constraints and predict periods of high net load variability are key elements of ramp capability dispatch designs and the California ISO experience has shown how complex the necessary analysis of net load forecast uncertainty can be with high levels of solar generation, particularly behind the meter solar generation.[50]

Another operational issue impacting the real-time dispatch (and the look-ahead real-time unit commitment) that the NYISO will need to address is the potential for operators to respond to ramp issues by adjusting the load forecast in RTC and RTD with the intent of creating more ramp capability.[51] While it is

50 The California ISO initially sought to estimate the variability of net load using recent data for exactly the same time of day. However, such an approach runs into the statistical constraint that a lot more data is required to reliably estimate the variability of a distribution than to reliably estimate its mean. The California ISO found that its estimate of the variability of net load, and hence of the need for ramp capability, varied tremendously over short periods of time as a few extreme outcomes moved in and out of the sample used for forecasting. Using data over the same hour rather than the same 5-minute time period on prior days provides more data points and stability in the estimates, but also leads to larger forecast error in hours at the beginning and end of the day when solar output can be changing relatively rapidly over some hours. Moreover looking further back in time to add data points with the goal of improving the estimate of net load variability, adds days to the sample but adds days with increasingly different sunrise and sunset times, particularly during the times of year when days are lengthening or shortening relatively rapidly from day to day. And accounting for these factors impacting the variability of solar generation is further complicated if the solar generation is behind the meter and the ISO forecasters cannot observe the change in solar output but only the change in net load.

These complications are not unsolvable but they create complex analytical challenges that are reasons that it would be desirable to begin addressing these analytical issues well before the time comes when it is necessary for the New York ISO to implement a ramp capability dispatch. Further discussion of these issues can be found in California ISO, Department of Market Monitoring, 2016 Annual Report on Market Issues and Performance, May 2017 pp. 110-111; Warren Kazenstein, California ISO, “Flexible ramping constraint discussion,” Market Surveillance Committee Meeting, February 11, 2016. Roger Avalos, California ISO, Department of Market Monitoring, “Briefing on Flexible Ramping Product,” Market Surveillance Committee meeting, July 15, 2015. California ISO, Department of Market Monitoring, Comments on Demand Curve in the Flexible Ramping Product Draft Technical Appendix,” June 15, 2015, as well as in Joe Cavicchi, Scott M. Harvey, “Ramp Capability Dispatch and Uncertain Intermittent Resource Output,” Rutgers Center for Research in Regulated Industries, Advanced Workshop in Regulation and Competition, 31st Annual Western Conference, Monterey California, June 27-29, 2018, pp, 74-87

51 These adjustments can cause the software to commit additional generation, which can increase the amount of ramp capability available for dispatch, and to back down regulating units, which can provide more upward ramp capability in subsequent intervals.

important for operators to have the ability to adjust the net load forecasts flowing into RTC and RTD when the net load forecast is not reflective of expected with system conditions, these operator adjustments can create additional issues if these adjustments chronically result in uneconomic commitments and interchange schedules and thereby lead to distorted relationships between RTC and RTD prices and schedules.

d. Improving the NYISO's Real-Time and Day-Ahead Energy Market Processes

The NYISO's real-time dispatch design, real-time unit commitment processes and day-ahead market will all affect the NYISO's ability to efficiently and reliably balance load and generation in real-time with a much higher level of intermittent resource output.

#### Real-Time

The NYISO will need to focus on two potential gaps in the current market design that would potentially impact the performance of the real-time dispatch in balancing variations in intermittent resource output. The first potential gap, discussed above, is the need for the NYISO either to increase its spinning reserve target or to adapt a ramp capability dispatch design in order to have enough ramp capability available to balance load and generation in real-time with higher levels of intermittent resource output. The second potential gap is the continued need for the energy market to provide strong incentives for participation in the real-time dispatch.

#### Participation in the Real-Time Dispatch

The NYISO's real-time dispatch design is well suited to balancing variations in net load. Like the MISO and Ontario IESO, the NYISO's real-time dispatch simultaneously optimizes the dispatch of energy and scheduling of ancillary services in real-time. Also like MISO, the NYISO applies demand curves to the dispatch of energy that reduce the supply of ancillary services in real-time, the forward commitment process (RTC) or the day-ahead market.[52] This design enables the NYISO's real-time dispatch to be more flexible than the current California ISO design in balancing generation and load in real-time, and is the kind of design the California ISO has recognized a need to shift to over the next few years.[53] There are three caveats to the continued ability of the NYISO to use its existing market design and real-time dispatch to balance increases in intermittent resource output using the real-time dispatch that the NYISO should keep in mind in analyzing potential reliability gaps. First, the ability of the NYISO to effectively use its economic dispatch to balance variations in net load depends critically on flexible resources having a sufficient

52 The changes PJM recently filed with FERC in docket ER19-1486 would implement a similar design in PJM.

53 See most recently Don Tretheway, California ISO, "Day-ahead market enhancements – flexible ramping product," Market Surveillance Committee Meeting, January 25, 2019.

economic incentive to participate in the NYISO economic dispatch, rather than submitting price taking bids corresponding to their day-ahead market schedules, and to offer their full ramp capability, and perhaps make investments to increase their ramp capability. The NYISO's market design generally provides strong incentives for flexible resources to participate in its economic dispatch.[54]

However, the incentive to respond to marginal incentives in the energy market is not present for resources that are committed uneconomically and are made whole with uplift payments. Energy market prices will not provide efficient incentives for participation in the economic dispatch or investments in greater operational flexibility if a large proportion of unit commitments are uneconomic (with the outcome that incremental energy margins do not contribute to profits but only reduce uplift payments) and resources earn profits by inflating their minimum load and start up offers, rather than by responding to the economic dispatch. It is therefore important for the NYISO to track the extent to which flexible resources are committed economically in real-time and made whole with bid production cost guarantee payments and attempt to correct any market design elements that are materially contributing to a need for bid production cost guarantee payments for such flexible resources.

The NYISO's ability to maintain efficient marginal incentives in the energy market and avoid materially increased reliance on bid production cost guarantee payments will depend in part on the structure of future contracts used to subsidize investment in intermittent resources. If the structure of future contracts creates incentives for many intermittent resources to offer their output at or near the current NYISO bid floor of -$1000 per megawatt hour, the potential for very negative prices will adversely impact the economics of many NYISO operating decisions, including the economics of committing thermal resources providing spinning reserves, upward balancing, frequency response and reactive power. [55] Highly negative real-time prices also have the potential to materially weaken energy market performance incentives because they would increase the likelihood that dispatchable resources would typically be receiving bid production cost guarantees to recover real-time commitment costs and hence would have little potential to profit from better real-time operating performance.[56]

In addition, the potential for real-time prices to fluctuate rapidly between positive prices and extreme negative prices, particularly prices near -$1000 per megawatt hour, have the potential to adversely impact

54 The California ISO has adjusted elements of its market design over the past five years to be more like the New York ISO market design with the goal of encouraging flexible resources to more fully participate in the California ISO's economic dispatch.

55 Intermittent resource output is typically offered in NYISO and other ISO markets at prices well above the NYISO's -$1000 bid floor, with tax and regulatory incentives generally incenting offers in the -$15 to -$150 range. There are, however, instances in which tax and regulatory incentives result in supply being offered at extreme negative prices, which can create difficult to resolve market and operational problems. It is important that future regulatory, contract and tax subsidies be implemented in a manner that avoids creating inefficient incentives for supply to be offered at extreme negative prices that do not reflect the social cost of curtailing the output.

56 The California ISO has maintained a bid floor of -$150 and Ontario IESO requires wind resources to offer supply at prices no lower than -$5.

the degree to which flexible resources would participate in the real-time dispatch and/or day-ahead market and would potentially have a variety of adverse market and reliability impacts that are difficult to completely anticipate.

Second, the application of hybrid (Fixed Block) pricing to dispatchable resources that are committed and kept on line in order to provide reserves (as ordered by FERC in EL18-33) could result in substantial inconsistencies between settlement prices and the economic dispatch. These inconsistencies could incent flexible resources to self-schedule their output rather than participating in the economic dispatch, incent intermittent resources to submit price taking, rather than economic offers, and incent dispatchable resources to increase their minimum operating level.[57] The NYISO is considering ways to minimize such inconsistencies as it tests methodologies to incorporate the commitment costs of fast-start resources into the calculation of real-time prices.[58] These incentive issues will need to be addressed before the level of intermittent resource output in New York rises to a level that will at times require dispatchable fast start resources to be on line to provide reserves and ramp despite being uneconomic in the energy market.

Third, the ability of the NYISO to manage increases in intermittent resource output is subject to the issues regarding net load forecasting discussed in subsection (e) below. The real-time dispatch will only be effective in balancing rapid increases in potential intermittent resource output if the increases are foreseen in the net load forecast that is utilized for the real-time dispatch.

#### Intra-day Unit Commitment

One step back from the real-time dispatch is the time frame in which the NYISO commits quick starting generation and schedules net interchange over the operating day. The New York's RTC currently makes these commitment and interchange scheduling decisions to meet a deterministic load forecast at least-cost. As the amount of intermittent resource output in New York increases, this net load forecast will be less accurate than it is today. The NYISO may need to modify RTC to account for load forecast uncertainty so it will commit generation and schedule interchange to maintain sufficient ramp capability to balance load and generation in RTD.

The MISO and California ISO have met this challenge by including target levels of upward and downward ramp capability in the objective function of their look-ahead unit commitment tools.

57 These inefficient incentives could be addressed, in part, by implementing constrained off payments to flexible resources that are dispatched inconsistently with settlement prices, but this resolution could result in very substantial uplift costs because of the large potential difference between the price of energy set by the fast start pricing design and the incremental dispatch price for constrained off intermittent resource output. A better approach would be to limit the extent to which resources that are on line to provide reserves or ramp capability can set energy prices, but it will take time to design such an approach and get it approved by FERC.

58 See NYISO, Enhanced Fast-Start Pricing, ICAPWG May 30, 2019 at this link: https://www.nyiso.com/documents/20142/6785167/053019%20MIWG%20-%20Enhanced%20Fast%20Start%20Pricing.pdf/dab2227c-e7ef-f7bf-194c-fdc8180809cd

The California ISO's look-ahead unit commitment tool (RTPD) is modeled after the NYISO's RTC, so the two programs have very similar functionality. We believe that the NYISO's RTC can readily be modified to implement ramp capability targets. The key challenges for the NYISO would be to: 1) determine appropriate ramp capability targets that reflect the expected variability of net load over the day and at different times of year; 2) develop workable locational ramp capability targets; and 3) set appropriate penalty prices for using ramp capability to balance load in the current dispatch interval. The NYISO's Reserves for Resource Flexibility project seeks to evaluate these challenges, by studying the future need for the NYISO to procure additional 10 and 30 minute Reserves beyond minimum requirements. As part of this project, the NYISO is exploring methods to calculate and predict net load forecast uncertainty.[59] The NYISO could potentially leverage this work in the future to help set ramp targets for different time horizons, such as one or two hours ahead for RTC.

While RTC can be modified to take account of net load forecast uncertainty and the need for ramp capability in RTD in making commitment and interchange scheduling decisions, the reduced accuracy of the net load forecasts used in RTC will lead to less efficient unit commitment and interchange scheduling decisions.[60] Moreover, there are a number of market issues that will tend to require more complex optimization decisions in the NYISO's intra-day unit commitment processes, which will tend to extend solution time and increase the latency of the load forecasts used to make unit commitment decisions. One approach the NYISO could take to mitigate these impacts would be to move commitment decisions for quick start units into RTD,[61] so they would be less impacted by the latency in the net load forecast and potentially to also move some interchange scheduling into RTD.

A third challenge confronting the NYISO's intraday unit commitment programs will be the need to manage the output of energy-limited resources over the operating day, including the need to schedule interchange and commit thermal generation to maintain energy balance. These challenges are discussed under topic 4 (Maintain Ability to Meet Daily Energy Requirements) below.

59 See NYISO, Reserves for Resource Flexibility, ICAPWG May 6, 2019 at this link: https://www.nyiso.com/documents/20142/6474763/5_9_2019_Reserves_for_Resource_Flexibility_FINAL.pdf/f5b74852-2b18-9233-a8fa-bfc488ed1238

60 Increased load forecast error would tend to increase bid production cost payments to resources committed in real-time, undermining market incentives. There may be a longer term need for financially binding intra-day commitment schedules. This is related to the discussion of the possible role of intra-day markets in supporting the efficient balancing of intermittent resource output, see, for example Arthur Henriot, "Market Design with Centralized Wind Power Management: Handling Low-predictability in Intraday Markets," Energy Journal Vol 35, # 1 2014 pp. 99-118, Kristof De Vos and Johan Driesen, "Balancing Management Mechanisms for Intermittent Power Sources – A Case Study for Wind Power in Belgium," Karsten Neuhoff, Carlos Batile, Gert Brunekreeft, Christine Vasilakos Konstantinidis, Christian Nabe, Giorgia Oggioni, Pablo Rodilla, Sebastian Schwenen, Tomasz Siewierski and Goran Strbac, "Flexible Short-Term Power Trading: Gathering Experience in EU Countries," Berlin 2015; and Frieder Borggrefe and Karsten Neuhoff, "Balancing and Intraday Market Design: Options for Wind Integration, Berlin January 2011.

61 This would be moving back to the functionality that was present in SCD at NYISO start-up, enhanced with the look-ahead capability of RTD.

### Day-Ahead Market

As the level of intermittent resource output in New York increases, the NYISO may at some point need to begin explicitly modeling the need for upward ramp capability in the day-ahead market. The MISO began including a requirement for upward ramp capability in its day-ahead market in 2016. The California ISO is in the process of developing such a requirement.[62] We believe the NYISO day-ahead market design and engine are well suited to implementing day-ahead ramp capability targets as they become needed. As with RTC, the key issues with meeting flexibility targets in the day-ahead market will be to 1) set appropriate ramp capability targets over the day, and 2) develop locational requirements.

A related set of day-ahead market reliability gaps concern the design of the NYISO forecast load pass and the reliability commitment. While the NYISO reliability commitment design has worked very well over the past 20 years, providing an assurance that sufficient resources will be available to meet real-time load while having minimal impact on day-ahead market commitments and prices, this design may need changes to better maintain reliability in a market with substantial net load forecast uncertainty and potentially limited incentive for the operators of intermittent resources to participate in the day-ahead market.

The MISO and California ISO have experienced relatively limited participation of intermittent resource operators in the day-ahead market, in part because of the structure of the contracts that subsidize those resources output.[63] While virtual supply offers tend to compensate for intermittent resource output that is not offered in the day-ahead market, many virtual supply bidders lack direct insight into the likely output of specific resources and instead must submit offers that approximate the expected impact of the intermittent supply on real-time prices.[64] More accurate scheduling of likely intermittent resource output may be needed as the level of intermittent resource output in the NYISO increases and it becomes more expensive to have excess thermal capacity on line in real-time. In addition, as the level of intermittent resource output rises, it will become more important to explicitly account for the potential variability and unpredictability of intermittent resource output in the forecast load commitment. These changes may require that the NYISO not only account for ramp needs in the day-ahead market but make associated changes in the design of the forecast load pass in the day-ahead market, including potentially providing

62 See most recently, California ISO, "Day-Ahead Market Enhancements Phase 2: Flexible Ramping Product," February 28, 2019 and Don Tretheway, California ISO, "Day Ahead Market Enhancement Status and Next Steps," May 2, 2019.

63 See, for example, California ISO, Market Performance and Planning Forum, April 18, 2019 pp. 30-31; Potomac Economics, IMM Quarterly Report: Winter 2019, March 19, 2019 p. 26.

64 In some cases, the virtual bidder is the load serving entity to which the intermittent resource is under contract and the load serving entity has access to information regarding the expected output of the resource. This is not necessarily the case however, depending on the structure of the contracting process for subsidized intermittent resource output.

market based compensation and assigning financial commitments to resources scheduled to meet load in the forecast load pass.[65]

Another potential reliability gap is the hour-long time frame of the day-ahead market schedules combined with the limited look-ahead capability of RTC. If long-starting resources are used to balance load during the evening solar ramp, it will be important that they come on line when they are needed during the hour, and not all come on line at the beginning of the hour when their operation could require dispatching down intermittent resource output at low or negative prices. The California ISO has been considering the implementation of 15-minute scheduling intervals in its day-ahead market to address these issues,[66] but has encountered challenges solving that many discrete intervals in the time frame of the day-ahead market that have led to the deferral of such a design.[67]

An alternative approach would be to lengthen the time horizon of intra-day commitment scheduling tools that solve in 15-minute intervals and to use them to determine the commit time for slower starting resources. This approach might be combined with changes to the NYISO two settlement rules that would insulate resource from two settlement charges for the difference between their day-ahead market schedule and real-time commitment schedule times.

Another set of changes impacting the design of the NYISO day-ahead market are those that will make it more expensive, potentially at times much more expensive, to have more than the minimum number of thermal units on line during low priced periods when intermittent resource output is high. This may create a need for the NYISO to optimize not only the supply of regulation, spinning reserves and ramp across a limited set of on line resources — but also to coordinate this with the commitment of resources needed to provide voltage support and perhaps frequency response.

The NYISO's day-ahead market software will provide a framework for evaluating unit commitment decisions but changes may be needed to both the optimization capabilities of these designs (including granularity, ability to account for energy and voltage limits, frequency response needs, replacement reserves and locational capacity requirements with carefully considered penalty price designs) and in the optimization horizon.

65 Hence, the best way to address these issues is by utilizing contract structures that combine subsidies with efficient incentives to participate in the day-ahead market.

66 An important motivation for the California ISO to evaluate the use of 15-minute schedules has been the potential ability to schedule cascade hydro resources in the U.S. Pacific Northwest and western Canada to meet the evening solar ramp if these resources could be scheduled day-ahead with sufficient granularity.

67 See, Don Tretheway, California ISO, "Day Ahead Market Enhancement Status and Next Steps," May 2, 2019.

e. Managing Net Load Forecast Uncertainty

As the level of intermittent resource output within the NYISO increases, the NYISO's ability to balance load and generation will be impacted by the latency of the net load forecast used in RTD. An important factor impacting the ability of the California ISO to balance load and generation with a resource mix that includes large amounts of intermittent resource output, particularly behind the meter solar generation, has been the latency in the net load forecast that is used in the real-time dispatch. The total load forecast latency arising from the length of the dispatch interval, RTD solution time, and the total calculation time for the net load forecast in the California ISO real-time dispatch can amount to 20-minutes or longer. The consequence is that there can be substantial generation available to balance net load in RTD that is not instructed to adjust its output in the direction needed to balance load and generation because of these time lags. Not only do these time lags mean that it could take 20 minutes or more before the real-time dispatch signal begins to move in the direction needed to balance load and generation, the dispatch signal can remain out of balance for even longer periods as the net load forecast continues to lag changes in real-time output.[68]

This net load forecast latency has contributed to situations in which the California ISO is unable to balance load and generation over sustained periods because the RTD dispatch is based on net load forecast that is 20 minutes out of date and does not show the imbalance, with the result that regulating capacity is completely utilized, with the regulating resources pinned at the upper limit of their regulating range.[69] The NYISO needs to be prepared to deal with the impact of load forecast latency in its real-time dispatch as the level of solar generation, particularly behind the meter solar generation, increases in New York.

Such an increase in load forecast latency would also impact the NYISO's CTS scheduling, which could become even more challenging as the level of intermittent resource output rises in New York and in adjacent regions such as ISO-NE.

One option for the NYISO in managing the impact of load forecast latency in RTD would be to pursue the approach the California ISO has been taking over the past year, seeking to reduce the amount of latency

68 This load forecast latency and the resulting net load forecast error, combined with high ramp needs, has led over time in the California ISO to a very high level of manual load forecast adjustments by California ISO operators (load bias or load conformance adjustments in California ISO terminology). These ad hoc manual adjustments have become large and frequent, impacting 60-80% of all RTD intervals and averaging hundreds of megawatts 2016, 2017, and 2018 see for example California ISO, Department of Market Monitoring, 2017 Annual Report on Market Issues and Performance, June 2018, Figures 9.15 and 9.11 and California ISO, Department of Market Monitoring, Q4 2018 Annual Report on Market Issues and Performance, February 13, 2019, Table 2.2,. Similar large ad hoc manual adjustments to the load forecast are being made in California ISO's intra-day commitment software and the operators are also making ad hoc adjustments to when updated load forecasts flow into RTD. Cascading operational impacts such as these from increasing net load forecast latency and error would have the potential to create substantial challenges for the New York ISO in reliably operating the New York transmission system.

69 California ISO, Market Performance and Planning Forum, December 18, 2017 pp. 4-13; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55

in the load forecast. This could involve both changes in load forecast methodology and incremental reductions in RTD solution time.[70] Another option would be an approach that has not been taken in California but could be considered in New York which would be to require roof top solar vendors to provide aggregated regional output data to the NYISO in real-time as opposed to the 15-minute frequency granularity that is received today.

While minor improvements in net load forecasting and RTD solution time such as those entailed by the approaches outlined above may be sufficient to keep load forecast latency within an acceptable range given the characteristics of the NYISO resource mix, there is no assurance that such an approach will be successful. Moreover, while load forecast latency could be reduced by modifying RTD to solve faster, there will be conflicting needs for RTD to look out further in time and potentially make additional optimization choices (such as short-term unit commitment), which would tend to increase RTD solution time and increase load forecast latency. Hence, other approaches to managing the impact of net load forecast latency on the NYISO's ability to balance load and generation may be required, including approaches that could involve more substantial changes in real-time dispatch tools and dispatch methods that would take a number of years to develop. For example, the forecast latency arising from RTD solution time could be addressed by abandoning multi-interval optimization in the real-time dispatch and shifting to an RTD design that solves a single interval dispatch extremely quickly, in less than a minute, as is the case in ERCOT.[71] Simplified fast solving methods might also be developed for adjusting the current net load for any intermittent resources being dispatched down so that the overall net load forecast latency might be reduced to a minute or two.

#### f. Promote More Frequent Interchange Scheduling with Neighboring Regions

When CTS was being developed it was hoped that the implementation among PJM, NYISO and ISO-NE would contribute to balancing sustained variations in intermittent resource output. However, it has proven challenging to develop sufficiently accurate load and price forecasts to achieve these benefits in the time frame of the CTS implementation in RTC.

It is noteworthy in this context that an important component of the California's ISOs strategy for

70 For recent California ISO discussions of forecast error and latency, as well as California ISO efforts to reduce forecast latency, see California ISO, Market Performance and Planning Forum, June 11, 2018 pp. 23-32; Amber Motley, California ISO, "Flexible ramping product requirements and load forecast discussion," Market Surveillance Committee Meeting, June 7, 2018; California ISO, Market Performance and Planning Forum, February 20, 2018 pp. 29-34; California ISO, Market Performance and Planning Forum, December 18, 2017 pp. 4-13; California ISO, Market Performance and Planning Forum, May 16, 2017 pp. 43-51; California ISO, Market Performance and Planning Forum, July 21, 2016 pp 41-55.

71 Alternatively a more complex RTD design could perhaps be developed in which real-time dispatch instructions are determined in a single interval optimization with upper dispatch limits and penalty prices input into that single interval dispatch from a multi-interval optimization that would postures resources to be able to respond to known ramps in future intervals. Such a design would attempt to retain the benefits of multi-interval optimization in posturing generation to be able to balance generation and load during predictable ramps while also maintaining the ability to solve quickly and respond to unexpected changes in net load.

balancing high levels of intermittent resource output has been to reduce the latency of interchange scheduling with adjacent balancing areas by implementing the western EIM, enabling interchange to be adjusted on a 5-minute basis. The NYISO, ISO-NE and Ontario IESO balancing areas are all even smaller than the California ISO balancing area and they may need to achieve the critical scale for balancing intermittent resource output by developing methods for integrating the regional dispatches among the NYISO, New England ISO, Ontario IESO and Hydro-Québec in a more coordinated manner than has been possible with the CTS design.

We noted above the potential for increased use of the existing ACE diversity interchange framework in the context of regulation. Additional coordination methods that might be considered in the timeframe of the real-time dispatch include: 1) changes in the CTS design with ISO-NE that would operate like a regional energy imbalance market with a single 5-minute energy dispatch and could eventually be extended to coordination with Ontario IESO and Hydro-Québec, or 2) shifting the NYISOs CTS scheduling for the next 15-minute interval from RTC, into RTD's multiple interval optimization.[72] Both approaches to improved coordination would involve substantial changes so would take a number of years to implement, if they ca be proven workable. Implementation of such a regional 5-minute dispatch that would take account transmission constraints within the entire region might also enable the northeast balancing areas to make better use of the ACE diversity interchange design.

### 2. Maintain Ten-Minute Operating Reserves

Potential Reliability Gap # 2: The NYISO may be challenged to maintain ten-minute operating reserves and meet NERC disturbance control performance requirements in response to variations in the levels of intermittent generation.

NYISO Plan for Gap # 2: The NYISO will continue to track ten-minute operating reserves and applicable NERC Balancing Area Disturbance Control Standards and implement necessary operational and market changes in order to maintain acceptable control performance. *Such changes are detailed in the following section and include:*

a. Increasing statewide ten and/or thirty-minute reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

**Background:**

72 With such an approach, RTC could continue to be used for the forward evaluation of interchange schedules that would be exchanged with other markets, but the scheduling of interchange for the next 15-minute interval would be shifted into NYISO's RTD.

We noted above that the scheduling of additional spinning reserves or ramp capability could play an important role in enabling the NYISO to balance load and generation as the New York resource mix evolves towards a substantially greater reliance on intermittent resource output. However, these increases in the level of intermittent resource output used to meet load on the NYISO transmission system also have the potential to impact the way the NYISO meets its spinning and total reserve targets in a number of ways that will need to be considered by the NYISO in parallel with these changes.

First, there may be a need for changes in the way the NYISO identifies and schedules reserves to balance the system following "contingency events." As the NYISO resource mix changes, the largest short-term unexpected reductions in generation within the NYISO may be a result of changes in intermittent resource output rather than conventional generation outage contingencies. This evolution in the resource mix will create the need for the NYISO to identify and protect against these events.

Second, these same changes in the resource mix will result in typically low energy price levels over many hours of the day, making it more expensive, potentially much more expensive, to keep thermal resources with minimum stable operating levels on line to provide contingency reserves or to maintain the ability to balance load and generation when intermittent resource output falls. These price and cost changes will create a strong incentive for the NYISO to meet its spinning reserve targets with resources that are able to provide reserves without generating material amounts of energy, This will in turn require the NYISO to evaluate its ability to rely on spinning reserves provided by a variety of resources other than thermal generation and to identify any limitations on the proportion of reserves or balancing energy that can reliably be provided by particular types of resources.

Third, these changes in the resource mix and associated low energy prices have the potential to lead to market outcomes in which the price of spinning reserves is low, providing little incentive for an increased supply of resources able to provide spinning reserves, but the full cost of spinning reserves, including the commitment costs of reserves provided by thermal generation, is high. Hence, as these changes in the resource mix and wholesale energy price level occur, the NYISO will need to assess whether its reserve pricing design is providing an efficient price signal.

Fourth, these changes in the resource mix and energy price levels have the potential to result in storage resources being used to meet a significant portion of the NYISO's spinning reserve requirement. In addition to the need to assess its ability to rely on varying levels or proportions of storage resources to provide spinning reserves, these changes will make it more important for the NYISO to manage the energy balance of resources providing reserves and meeting energy demand throughout the day.

We discuss each of these potential reliability gaps below.

#### Contingency Reserve Targets

The level of intermittent resource output on the NYISO system is currently low enough that even large proportional changes in intermittent resource output are small relative to the size of the generation and transmission outage contingencies the NYISO maintains reserves to recover from. This relative balance will likely cease to be the case at some point in the future as intermittent resource output rises and the absolute size of the short-term variations in intermittent resource output become larger.[73] This potential reliability gap is related to the discussion of ramp and energy market balancing in Section 1, but the ramp capability dispatch would schedule additional ramp based on targets and a demand curve. The NYISO might need to undertake an assessment of its ability to recover from a large reduction in intermittent resource output using a combination of spinning reserves and potentially resources providing upward ramp capability that would be enforced at a higher penalty price than its procurement of flexible ramping capacity.

The NYISO will need to track and evaluate the magnitude of potential contingencies or other unpredictable short-term changes in intermittent resource output as the resource mix evolves. In addition, the NYISO will need assess on an ongoing basis and project how the magnitude of these unpredictable supply changes will likely change with prospective changes in the resource mix.[74] This assessment will be used to guide any needed changes in NYISO spinning reserve targets and shortage prices.

The NYISO might also find it necessary or desirable to develop tools that more accurately and dynamically model locational reserve requirements taking into account transmission loadings and unit commitments. Such improvements would potentially allow the NYISO to more accurately model the amount and location of the spinning and total reserves across the system so as to reduce the need to commit additional thermal resources at minimum load in order to provide reserves.[75] The NYISO is currently considering the implementation of Load Pocket Reserve areas in NYC, which could be accomplished more efficiently via a dynamic methodology considering load pocket transmission loadings.

---

73 An example of additional types of contingencies that might need to be protected against is the tripping of solar generation in connection with faults on the transmission system. NERC identified this risk in 2017 and the level of solar generation on the California ISO grid required that the California ISO schedule operating reserves to protect against a contingency in which 25% of forecast solar output, later reduced to 15%. The California ISO typically carries ½ of its operating reserves as spinning reserves, See California ISO Market Notices of June 12, 2017 and September 14, 2017 and California ISO, Department of Market Monitoring, 2017 Annual Report on Market Issues & Performance, June 2018 pp. 141-143.

74 As the level of intermittent resource output rises, this evaluation will eventually need to be dynamic, with the required level of reserves declining when intermittent resource output is low (and hence there is no potential for large contingencies involving sudden reductions in intermittent resource output). If the New York ISO attempted to maintain a fixed spinning reserve margin that was sufficient to cover large reductions in intermittent resource output even intermittent resource output is low, meeting this reserve target would require committing additional thermal generation and further increasing emissions, in addition to the generation used to meet load when intermittent resource output is low.

75 The California ISO has developed such a tool, referred to as commitment modeling enhancements. These improvements are slated to be implemented in combination with other improvements to the design of the day-ahead market, see http://www.caiso.com/informed/Pages/StakeholderProcesses/ContingencyModelingEnhancements.aspx

**Spinning Reserve Resource Mix**

At the same time that the size of the NYISO's largest generation contingency may increase, the cost of scheduling spinning reserves on thermal units is likely to rise substantially with the increasing output of intermittent resources. In particular, increased output from intermittent resources with negative incremental costs associated with subsidies tied to megawatt hour output levels, will likely cause middle of the day energy prices to gradually fall until they frequently reach negative levels. These changes in energy prices will make it more and more costly for the NYISO to keep thermal resources on line at minimum load in order to provide spinning reserves (or upward ramping capability).[76]

These cost pressures will require the NYISO to assess how much of its spinning reserve requirement can be concentrated on particular resources that can provide spin without incurring substantial minimum load costs,[77] and to evaluate its ability to rely on various types of storage and other non-generation resources to provide spinning reserves.

The NYISO's simulations reported in the December 2017 *Integrating Public Policy* report projected some increase in day-ahead market spinning reserve prices, but some elements of the reported simulation results suggest that future spinning reserve prices might be materially higher than projected in the report.[78]

The likely high cost of spinning reserves provided by thermal units will also require the NYISO to evaluate its reliability rules relating to the supply of spin from other types of resources and establish appropriate rules. This could, for example, involve rules allowing import supply of spinning reserves from external balancing areas, resource designs in which thermal resources are providing spin but not generating energy (PJM operates CTs in this way), designs in which a combination of batteries and very quick starting thermal resources provide spinning reserves,[79] spinning reserves provided by directly controlled and monitored load, and the provision of spinning reserves by inverter based resources, etc. The NYISO's flexibility to revise its spinning reserve supplier requirements may be limited by rules written by bodies such as the NPCC and NYSRC, which have oversight of reliability rules, so NYISO efforts to close reliability gaps may require working with these organizations to align reliability rules with evolving technology and resource capabilities.

76 This discussion focuses on spinning reserves as targets for 10-minute reserves can be met with off line resources.

77 We believe this is the case, however, we have not reviewed Niagara's ramp rate or its ability to provide spin at low output levels.

78 The price simulations in Figures 58-64 tend to show positive day-ahead market prices and very negative real-time prices.

79 Quick starting resources can provide 10-minute non-spinning reserves under the current New York ISO tariff. This comment refers to the possibility of a supplier providing spinning reserves with a combination of a battery able to provide an immediate response, but only for a short period of time, and a quick starting unit, that could not respond immediately but could come on line before the battery has depleted its storage.

In addition, as the amount of spinning reserves provided by energy limited resources such as energy storage rises, the NYISO may need to evaluate whether: 1) there needs to be a cap on the proportion of spinning reserves provide by particular types of resources; 2) restrictions are needed on the number of successive hours energy limited resources can be scheduled to provide reserves in the day-ahead market;[80] and 3) whether a one hour sustainability requirement for all resources providing spinning reserves is sufficient to meet reliability needs.

#### Spinning Reserve Price Formation

Absent a substantial change in the NYISO resource mix, resources able to provide spinning reserves without incurring minimum load costs, such as pondage hydro, pumped storage, energy storage and perhaps other types of resources will be able to submit high offer prices for spinning reserves that would and should clear in the day-ahead because they will provide reserves at much lower costs than could thermal units. These higher spinning reserve prices will reduce the uplift payments to thermal resources committed out of merit to provide spinning reserves, and will also provide a price signal for the supply of spinning reserves for resources that do not need to incur minimum load costs in order to provide spinning reserves.

A complicating factor in meeting these evolving resource needs for spinning reserves is that the likely high cost of relying on thermal resources to provide reserves during hours in which energy prices are low or negative will not necessarily be reflected in reserve prices under the NYISO's current market design. Instead, reserve prices could be set by incremental reserve offers, while thermal resources committed to provide reserves incur large uplift costs. These incremental reserve prices would not provide an efficient price signal for investment in resources able to provide reserves without selling a material amount of energy in the spot market.

It is possible that suppliers able to provide spinning reserves from resources that do not incur minimum load costs in providing reserves will submit offers at levels that will clear in the market and displace thermal resources, while sending an appropriate price signal for the supply of spinning reserves. Relying on resource offers to provide an efficient price signal in these circumstances rests on a hope that there will be just enough exercise of market power. This is unlikely to be the case. There is no assurance that suppliers will possess enough market power to raise prices closer to the efficient level, nor assurance that they will not have so much market power that they are able to raise prices when there is no shortage of spinning reserves from such resources. Nor is it apparent that they would even have the ability to figure out the bid level in the day ahead market that would raise prices while displacing thermal resources, given

80 Or alternatively, whether an energy limit needs to be enforced on the scheduling of reserves in the day-ahead market.

the multiple factors that would impact the cost of carrying reserves on thermal units (such as the price of energy at each location). Hence, we do not recommend relying on market participant offers to set reserve prices that send an efficient price signal in this situation.

A better approach would be for the NYISO to refine its demand curve for spinning reserves to send an appropriate price signal for all types of resources able to provide reserves. This will require a demand curve for spinning reserves that extends down to low shortage prices, as a demand curve with high penalty prices will cause thermal resources to be committed out of market with reserve prices set by their incremental reserve offers. As noted above, PJM has recently filed plans to implement such an approach with the FERC, and the NYISO is exploring introducing more steps in its shortage pricing design for reserves and regulation as part of its Reserves for Resource Flexibility project.[81]

A third possible approach would be to develop a pricing methodology that would incorporate the out of merit costs of thermal resources committed to supply spinning reserves into the price of spinning reserves. This would be in the spirit of the hybrid pricing design for fixed block units/fast start pricing but would be even more complex, if it were workable at all, and there is no assurance that a workable design of this type could be developed.

The NYISO will continue to monitor the level of day-ahead and real-time prices and the uplift cost of resources committed to provide spinning reserves and assess the need for changes in reserve shortage values of the price determination rules on an ongoing basis.

#### Management of Reserves Provided by Energy Limited Resources

As part of a broader need to track the energy as well as capacity balance of the New York electric system, as the level of storage resources used to meet load and provide reserves rises, the NYISO may need to develop more complex tools to track whether the resources scheduled to provide spinning reserves have sufficient energy to meet NYISO reliability needs above and beyond those that will be implemented as part of the current Energy Storage Resource design.[82] As the amount of energy limited resources relied upon to balance net load increases, the NYISO will need to not only assess whether the individual resources scheduled to provide reserves have enough energy to meet NYISO requirements, but to also assess whether the resources available to the NYISO in aggregate have enough capacity and energy to allow reserves to be restored following a contingency in which energy limited resources providing reserves have their reserves converted to energy.

81 See FERC Docket No. EL19-58-000 for PJM's 206 filing of Reserve Market Enhancements, submitted March 29, 2019
82 See the New York ISO Order No. 841 Compliance filing in FERC Docket ER19-467.

Reductions in the amount of thermal generation committed to meet energy demand during some periods of the day may require the NYISO to specify additional, or simply different, locational reserve constraints as commitment patterns change.

The inclusion of more energy limited resources such as batteries in the resource mix providing spinning reserves will also require changes in the way spinning reserves are scheduled and energy dispatched to ensure that resources scheduled to provide reserves have enough energy to sustain their output for the one-hour period required by the NYISO. This will require software that can both model energy limits and make optimal trade-offs between using energy in storage to meet load in the current period and reserving the energy in storage so the storage resource can provide more spinning reserves. While the basic framework of the NYISO's real-time co-optimization of energy and ancillary services within the multi-interval optimization framework of the real-time dispatch is well suited to evaluating these tradeoffs, there may be a need to evolve this design to: 1) model future RTD intervals more discretely and thereby better model ramp needs; 2) explicitly account for net load forecast uncertainty; and 3) explicitly account for energy limit impacts that extend beyond the current RTD horizon.

### 3. Maintain Total Thirty-Minute Operating Reserves

Potential Reliability Gap # 3: The NYISO may be challenged to meet NPCC Operating Reserve requirements to not be deficient in total balancing areas reserves for greater than four hours in response to longer term variations in the levels of intermittent generation.

NYISO Plan for Gap # 3: The NYISO will continue to track applicable NPCC Operating Reserve Standards performance and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Increasing statewide Total Operating (30-minute) Reserve procurement requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Account for increased real time load forecast uncertainty
d. Evaluate the sustainability of 10-minute and 30-minute reserves

**Background:**

We have noted several times above that the expected increases over the next 10 years in the level of zero or near zero incremental cost wind and solar output, both within the NYISO and in adjacent regions, potentially combined with output related regulatory and tax subsidies will likely cause middle of the day energy prices to gradually fall. These low energy prices will make it more and more costly for the NYISO, and adjacent balancing areas, to keep resources on line at minimum load beyond those needed to provide required reserves and regulation Low energy prices within the NYISO and in adjacent balancing areas during the middle of the day when intermittent resource output is high has the potential to reduce the ability of the NYISO to restore contingency reserves following outages because there will likely be much lower levels of latent reserves available not only within New York but also lower levels of latent reserves on line in adjacent regions. This market tightness will be compounded to the extent that the NYISO uses energy-limited resources, particularly resources with very limited energy supply such as energy storage, to provide spinning reserves. Not only will the NYISO need resources that will enable it to restore 10-minute reserves following contingencies, the NYISO will also need to replace the energy output of energy limited resources whose reserves have been converted to energy that they will not be able to sustain beyond the required one (1) hour minimum period.

The current reserve shortage design of the NYISO for 30-minute reserves would send an efficient price signal for the supply of resources able to provide 30-minute reserves. Hence, the current market design would incent suppliers able to provide 30-minute reserves to offer their supply in RTC so it could be scheduled to provide reserves, and if necessary energy, following contingencies if reserve prices rose due to a shortage of 10- or 30-minute reserves. Moreover, the supply offers of these resources in RTC would provide visibility to NYISO operators of the energy and capacity supply available to restore reserves.

There can, however, be a potential reliability gap to the extent that the resources that would be able to provide additional energy or reserves following a contingency would need to incur costs prior to real-time in order to be able to operate, such as gas fired generators that might need to schedule and potentially sell back gas or demand response resources that would need to take some advance actions in order to be able to provide reserves.

The NYISO current market design is well suited to addressing this potential reliability gap by scheduling additional 30-minute reserves in the day-ahead market, which need not be provided by on-line resources. Moreover, if the NYISO would be willing to go for an hour or more without restoring reserves following a contingency, the NYISO could develop a reserve product with a longer notification and start up time. The NYISO will need to analyze the potential need for replacement reserves as markets in the Northeast evolve over time and set appropriate 30-minute reserve targets and penalty prices. This will include analyzing the impact of relying on energy-limited resource to provide spinning reserves on the amount of replacement reserves needed to maintain reliability following a contingency.

Importantly, replacement reserves can be procured from off-line resources that would not incur minimum load costs in order to be available to restore reserves following a large contingency. If we anticipate energy prices are low during some hours of the day, the NYISO is likely to find it will be efficient and perhaps even necessary to rely much more on off-line units not only to provide contingency reserves but to restore contingency reserves and replace contingency limited energy reserves that have been converted to energy. This will require the availability of resources that can be brought on line within the relevant time frame and perhaps also require the development of different gas supply arrangements for those resources. One change to be evaluated is the availability of gas for replacement reserves if less thermal generation is operating, and less often operating above minimum load and will gas supply be available when gas fired resources need to come on line in the winter. This assessment will also need to take into account future changes in environmental restrictions on burning oil when gas prices are high or gas supply is curtailed. The NYISO may therefore need to develop rules that will ensure that replacement reserves will be available to restore contingency reserves in a market environment in which there are much less latent reserves available in the NYISO or in adjacent balancing areas.

The NYISO already procures 30-minute reserves based on a demand curve so the current design could be used to procure additional 30-minute reserves in the day-ahead market if real-time spot energy prices fall over time and less replacement capacity can be counted on to be on line in the NYISO or in adjacent regions in real-time.[83] However, any future reliance on energy limited resources to provide spinning reserves, 10-minute total reserves and 30-minute reserves will make it extremely important for the NYISO to develop mechanisms for evaluating and managing the energy balance of resources and the balancing area as a whole, both day-ahead, within the operating day and potentially over multi-day forward periods.

### 4. Maintain Ability to Meet Daily Energy Requirements

Potential Reliability Gap # 4: The NYISO may be challenged to meet NERC control performance requirements managing high levels of intermittent limited energy storage supply resources to meet daily energy requirements in real-time operations.

NYISO Plan for Gap # 4: The NYISO will continue to track applicable NERC Balancing Area Control Performance Standards and operating reserve criteria and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Developing new capability for operator management of limited energy supply resources

83 Another factor that may materially tighten the capacity balance in the northeast are the changes PJM has filed in the design of its reserve market. PJM currently commits for a 30-minute reserve requirement day-ahead which is not enforced in real-time. This design potentially makes substantial additional capacity available in in real-time, although the actual incremental impact is difficult to assess because it also impacts the scheduling of interchange and virtual bids in the day-ahead market. The tariff changes PJM has filed would apply a $2000 per megawatt penalty price to these reserves in real-time, which would effectively make them no longer available to support increased exports to the NYISO following the loss of a generating unit. The eventual impact of these changes in the PJM reserve market are difficult to assess, both because there may be differences between what has been filed and what will be approved by FERC, and because these changes will impact market participant behavior in PJM, New York, MISO and even utilities in SERC. Hence, it will be a few years before the impact of these changes will be apparent, but there will be an impact to tighten real-time markets in the northeast.

b. Increasing statewide ten and/or thirty-minute operating reserve

c. Account for real time load forecast and renewable uncertainty

Background:

If the NYISO becomes more dependent on the output of limited energy storage resources to balance variations in intermittent resource output and potentially relies on these resources to provide spinning reserves and regulation, the NYISO will need to be able to track the energy balance of these resources over the operating day. This information will enable the NYISO to assess the ability of these resources to provide reserves and to balance variations in intermittent resource output and take this capability into account in its dispatch, interchange scheduling and unit commitment decisions. As the role of storage or other energy limited resources expands, it will become increasingly necessary for the NYISO to develop systems for tracking the energy balance of energy limited resources participating in NYISO's energy and ancillary services markets so the NYISO's market and reliability processes do not count on resources being able providing services or supply that they will not be able to provide because of energy limitations.

In addition, the ability of storage resources and other energy-limited resources to efficiently and reliably contribute to balancing variations in intermittent resource output will require that their output be managed over the day to account for their energy limits. Hence, the NYISO will also need a market design that will allow the NYISO and its market participants to efficiently and reliably manage the energy balance of a significant number of resources with limited storage capability both in the day-ahead market and over the operating day, and potentially over multiple operating days.[84] If increases in the amount of energy limited resources relied upon to balance net load cause the NYISO system to at times become energy constrained over periods of hours or potentially days, maintaining reliability could require that the NYISO do more than simply track the state of charge/available supply of energy limited resources. The NYISO may need to track the overall energy balance and adjust dispatch and interchange schedules to maintain or restore the system energy balance in response to unexpected variations in intermittent resource output, transmission or generation outages, or curtailed imports. These energy limits would not only need to be enforced in the day-ahead market but in intra-day unit commitment and interchange scheduling decisions and in the real-time dispatch.[85]

84 In its Order No. 841 compliance filing, the NYISO described its plans to track the state of charge of Energy Storage Resources (ESRs) over the operating day in both the real-time and day-ahead markets. State of charge monitoring will only be applied to resources that are registered as continuously dispatchable, "must-run" ESRs. Operational experience with ESRs over the next several years should inform enhancements to the proposed design. The NYISO's approach to monitoring and/or managing storage energy levels could later be expanded to other types of energy limited resources, such as hybrid resources, pumped hydro, and certain types of DER.

85 For example, with a little storage on the system and enough thermal output to meet load at the net load peak, storage use can be optimized to reduce the output needed from the highest cost thermal resources. The cost to consumers would be reduced, however, if the storage were used to eliminate the need for some of the thermal generation in the capacity market, in which case the storage output would be needed to meet load over the net load peak. This would require that storage be used in a way that ensured it had sufficient charge to meet load in that net peak

The NYISO today largely relies on market participants to manage the use of their energy-limited resources with their offers prices and occasional communications with ISO operations. One approach that the NYISO could take as the role of storage resources increases would be for the NYISO to continue to rely on market participants to manage their energy limits within the current design.

There are, however, a number of reasons that the current approach to managing energy limits may become unworkable, particularly over the operating day, as the NYISO's reliance on batteries and other energy limited resources increases. First, the current management of energy-limited resources relies in part on interactions between resource operators and NYISO operators. These interactions are workable when applied to a small number of large limited energy resources, as is the case today, but would likely be very unworkable if applied to a large number of small energy limited resources.

Second, the current mechanisms for enabling market participants to manage the output of their energy limited resources using their offer prices, relies on ad hoc processes for avoiding mitigation of these offer prices. These mechanisms would likely also become unworkable if applied to a large number of resources. One way to resolve this problem would be to eliminate mitigation of the offer prices of most energy limited resources, but such an approach would need to be thought through and might require some accompanying market design changes.

Third, the current mechanisms are workable with the relatively long time frames for market participant offer price adjustments at least in part because the current energy limited resources have substantial storage relative to their capacity so their energy limits bind over a relatively long period of time. This makes it workable for them to manage their energy limits with offer prices that change once an hour with a 75-minute lag, and an occasional call to the NYISO operators. The current timing for offer price adjustment would likely not provide a workable framework for the operators of batteries and other energy limited resources whose storage to capacity ratio may only be an hour or two, even when full to manage their energy limits because the resources storage could be depleted before the resource operator would have an opportunity to adjust its offer price. Moreover, "occasional calls to operators" are workable if there are a handful of such resources, not if there are hundreds.

Fourth, in the past, energy limited resources in the NYISO market could manage their energy use while

load hour. This would in effect be a system minimum net charge requirement going into that peak hour. With further reductions in thermal generation, the storage output might be used to meet net load over several hours each day in which net load would exceed the output of thermal generation. This would require that storage be used in a way that ensured it had sufficient charge to meet load over those several hours, which could be ensured with a system minimum state of charge going into those several hours. With even less thermal generation and more reliance on storage, there could be overcast humid days on which thermal generation plus intermittent output would not be sufficient to meet load over the day, so the NYISO would need to enforce a system minimum state of charge for the end of the prior day to ensure that enough energy was available to meet load over the following day. While we have described the scenarios above as if the net load over the peak hour, hours or day were known in advance, this would of course not be the case and the NYISO would also need to account for net load forecast uncertainty, as well as the potential for generation and transmission outages, in setting these system minimum state of charge targets.

meeting market needs by reducing their upper operating limit or by offering supply in high output ranges at high prices. These adjustments were effective in managing energy limits in the past because the NYISO needed to use these resources to meet load over sustained periods so reducing the upper operating limit correspondingly reduced energy usage. With increasing levels of intermittent resource output, however, energy use may not be well related to the upper operating limit because resources may be dispatched up for short periods of time to balance variations in intermittent resource output, then dispatched back down when intermittent resource output rises, or other resources are able to ramp up. Hence, while in the past, if a resource was dispatched to an upper operating limit in excess of its day-ahead market schedule, this would generally result in increased energy usage over the hour. This will be much less certain in the future, as resources would often be dispatched above and below their day-ahead market schedule within the hour, potentially with little impact on the energy usage over the hour.

If resources were to continue to use adjustments to their upper operating limits or their offer prices to manage their energy limits as the NYISO resource mix changes, the upper operating limit or offer price that constrains the dispatch of the resource for energy throughout the hour could also constrain its dispatch up and down to balance intermittent resource output, seriously undermining the ability of the NYISO to use storage and other energy limited resources to balance substantial variations in intermittent resource output.

In maintaining the reliability of the New York electric system as the resource mix evolves, it may not be enough for the NYISO to simply analyze the energy balance over the remainder of the operating day or perhaps a long period given the offers of storage resources and rely on market participants to manage the energy state of storage resources. It may also be necessary for the NYISO to take actions to balance energy over the day. This could involve tradeoffs between using energy limited resource to balance load and generation now and refilling storage with imports later or between committed an internal thermal unit or relying on imports. A difficulty that both Ontario IESO and the California ISO have run into in attempting to evaluate the load and energy balance over the operating day, is the offer prices used for the evaluation of future hours are subject to change. Hence, it could appear economic to defer committing a thermal unit and rely on interchange to meet energy needs at the time when an initial evaluation is made, but then interchange prices could rise dramatically in future hours such that it would have been better to commit the resource. Conversely, imports or gas fired generation output may be available in future hours if there is forward financial commitment but may not be available in the time frame of CTS and RTC absent a financial commitment. If these kinds of issues become significant they might be addressed with some form of forward financial commitment based on advisory prices and schedules in a RTC like tool that scheduled generation and interchange.

The NYISO may therefore need to not only track the energy balance of storage and other energy limited resources, changes in the resource mix may require the NYISO to evolve its market design so that the NYISO takes on more responsibility for managing resource energy balance over the operating day. This role would likely require changes in the day-ahead market, in the role of RTC in scheduling interchange and committing generation during the operating day, and in the real-time dispatch (RTD). The changes impacting each of these time frames are briefly outlined below. In addition, if Energy Storage Resources are relied upon to meet load from the standpoint of resource adequacy, the NYISO will need to be able to evaluate, and be able to maintain, energy adequacy over multi-day periods of low intermittent resource output.

#### Day-Ahead Market

Software vendors already have the capability to enforce energy limits in the day-ahead market. The California ISO has had such limits in its day-ahead market since 2009, primarily to efficiently schedule the output of pondage hydro resources. The Ontario IESO is also planning to implement energy limits in its day-ahead market. The NYISO plans to implement energy limits for Energy Storage Resources in its day-ahead market.[86] This will be a somewhat more complex optimization problem than modeled in the California ISO software because the NYISO will be optimizing injections and withdrawals for Energy Storage Resources.[87]

#### Intra-Day Interchange Scheduling and Unit Commitment (RTC)

A need to manage energy limits of the overall NYISO resource mix over the operating day would require even larger changes in NYISO systems because for the NYISO to directly manage energy limits over the operating day in scheduling interchange and making unit commitment decisions would require a real-time unit commitment scheduling and dispatch system that would be able to look out at least over the balance of the operating day and potentially into the next day, to enable the NYISO's unit commitment and interchange scheduling decisions to reflect the NYISO's prospective energy balance. The NYISO's RTC only looks out around 3 hours, not nearly far enough out in time to account for daily energy limits within the program's current optimization horizon.

The Ontario IESO plans to account for intra-day energy limits by extending the horizon of its Enhanced Reliability Unit Commitment program to look out over the remaining hours of the operating day, and into the next day after day-ahead market results have posted. This design will require design compromises in

86 See New York ISO filing in FERC Docket ER19-467, December 3, 2019 and proposed MST sections 4.2.1.3.4, 4.4.1.1 and 4.4.1.2.

87 As observed above, as the level of reliance on storage resources to meet load increases, it may become necessary for the day-ahead market software to enforce minimum system state of charge requirements to ensure that enough energy will be available to the system to meet net load over the following day.

order to maintain a workable solution time, such as analyzing future intervals with hourly granularity. The California ISO has also examined extending the horizon of its look-ahead program, STUC, but these changes have been deferred for now.[88]

It is important for the NYISO to retain the 15-minute granularity of the RTC for interchange scheduling and evaluating commitment of quick start resources. If the NYISO were to take on a role of managing daily energy limits, and sought to optimize energy use over the day, the NYISO could consider approaches such as using an hour time step for the evaluation of the energy limit over periods many hours in the future.

On the other hand, if most of the Energy Storage Resources entering the New York market are short-term low capacity storage resources such as batteries, there may be little economic benefit from managing the storage levels of these resources over the day. If this is the case the NYISO might be able to use RTC with its current look-ahead timeframe for short-term management of resource energy limits, with minimum and maximum energy constraints (or state of charge constraints) for RTC based on day-ahead market schedules, or market participant offers, to manage longer term energy limits.

To the extent there are storage resources with larger storage capacities that need to manage daily energy limits, or resources with other types of daily energy limits (such as gas fired generation with a fixed supply of gas available over the day) the NYISO could utilize its current RTC look-ahead design, combined with minimum and maximum state of charge constraints and energy opportunity costs to manage resource energy limits. Energy limits, state of charge constraints and opportunity costs for the RTC look-ahead could be derived from day-ahead market schedules over the remainder of the day, updated over the day based on actual resource energy use or specified by the resource operator and updated each hour over the day. The schedules and opportunity costs calculated in RTC could then flow into RTD in the form of energy limits and opportunity costs.

#### Real-Time Dispatch (RTD)

There would also need to a way to reflect resource energy limits in the real-time dispatch, which currently looks out only an hour. There are a number of ways energy limits, state of charge constraints and/or opportunity costs could flow from RTC into RTD with a variety of strengths and weaknesses. While Order No. 841 imposes tariff requirements on the NYISO relating to the way storage resources would be enabled to participate in the NYISO market, it is not assured that either Order No. 841 requirements, nor the proposed storage resource designs of the NYISO or other ISOs will enable low capacity storage

88 http://www.caiso.com/Pages/documentsbygroup.aspx?GroupID=866A4566-F461-49F1-95EA-1B758E6BAAC7

resources to profitably participate in NYISO markets or to make a material contribution to balancing variations in intermittent resource output.

Depending on the evolution of the NYISO resource mix, the NYISO might need reliability mechanisms that would commit suppliers to provide specified amounts of energy over the next day, or perhaps multiple days. These changes would influence the gas scheduling (and oil stock) decisions of thermal generators, the use of water in storage and the supply of power from external balancing areas.

## 5. Transmission Operations and Congestion Management

Potential Reliability Gap # 5: The NYISO may be challenged to meet NERC Transmission Operations requirements when operating under high levels of intermittent generation with system and locational demand requirements that may be difficult to forecast in real-time operations.

NYISO Plan for Gap # 5: The NYISO will continue to track applicable NERC, NPCC, and NYSRC Transmission Operations Standards and implement necessary operational and market changes in order to maintain acceptable performance. Such changes are detailed in the following section and include:

a. Increasing transmission facility constraint reliability margins

b. Increasing locational ten-minute spin and total operating reserve requirements

c. Increasing locational thirty-minute total operating reserve requirements

d. Investigating the need for a locational (zonal) ramping product

e. Account for increased real time load forecast uncertainty

f. Monitor and manage sustainability

**Background:**

If the NYISO shifts to an operational pattern in which there are few thermal resources on-line during the peak intermittent resource output periods, the NYISO will need to ensure that it can continue to operate the transmission system in accordance with all applicable reliability requirements. As was the case when coal fired generation retired in western New York, the NYISO may find that new transmission constraints will bind that are difficult to manage given the lack of dispatch capability and impacts associated with intermittent resources. In addition, the implications of having reduced amounts of thermal generation on line and able to be dispatched up will need to be evaluated and addressed in the planning process as well as in the day-ahead market and real-time operations.

The NYISO should evaluate the potential variability in solar or offshore wind resource output within constrained regions in eastern New York and assess whether this variability would need to be modeled in contingency analysis to avoid transmission overloads. If there is a reliability need to model these output reductions as contingencies, the NYISO could consider developing systems that would evaluate these contingencies dynamically, linking the size of the contingency being protected against to the level and location of solar or wind output.

The NYISO may need new real-time tools that can analyze the transmission system impact of large reductions in intermittent resource output within constrained regions and dispatch the system to avoid overloads and commit or dispatch generation to ensure that the NYISO will be able to reduce flows following large reductions in intermittent resource output. These issues will include consideration by the NYISO and reliability organizations of modeling changes in intermittent resource output in a manner similar to generation or transmission outage contingencies.

The NYISO will also need to review the modeling of intermittent resources within the planning horizon and how potential levels of intermittent resource output should be accounted for in forward analyses of transmission security.

a. Increasing Transmission Facility Constraint Reliability Margin

In the near-term, the NYISO may have to rely on addressing these transmission operating reliability issues by increasing the reliability margin that the energy market models consider when securing transmission facilities. The constraint reliability margin typically ranges today from 10MW to 50MW. These margins could be increased to account for increased uncertainty in intermittent resource output and load forecast uncertainty.

b. Increasing Locational Operating Reserve Requirements

Another action to ensure that dispatchable resources are available to manage transmission operations would be to establish locational reserve requirements for those areas of the New York State transmission system that are expected to be subject to transmission constraints. There are currently locational reserve requirements for the Eastern New York, Southeast New York, and Long Island Zones, and the NYISO has recently implemented a NYC Zone requirement.[89] Today, the values of locational reserve requirement are based on an expected need for generation response capability to address a locality transmission or generation contingency and a forecast of the zonal demand during the response period (typically a 30-minute period to re-secure the transmission system). Under a future system with high levels of intermittent resources, the values for locational reserve requirements may need to be increased to reflect the generation response uncertainty as well as the load forecast uncertainty in the response period and might

89 See New York ISO filing in FERC Docket ER19-1678 April 26, 2019, accepted by FERC June 21, 2019.

need to also manage resource energy limits so as to maintain sufficient energy within potentially transmission constrained regions.

c. Investigating the Need For a Locational Ramping Product

Similar to the discussion for a ramping product for balancing load and generation, there may be benefits to having a ramping product available on a locational basis to address those areas of the New York State transmission system that are expected to be subject to transmission constraints. Such a locational ramping product could provide an additional means (in addition to that provided by locational reserve requirements) to ensure sufficient locational dispatch capability is available to manage transmission operations.

## 6. Restoration and Black Start Capability

Potential Reliability Gap # 6: The NYISO may be challenged to effectively restore the system within expected timeframes following a blackout given a system with high levels of intermittent generation.

NYISO Plan for Gap # 6: The NYISO will implement and monitor the effectiveness of established NERC and NYSRC Standards and procedures that require acceptable statewide and NYC restoration and black start capability performance are maintained as system changes occur through time. Such changes are detailed in the following section and include:

a. Annual Review and Update of Restoration Plan
b. Coordination of NYISO and Transmission Owner Restoration Plans
c. Facilitate participation of resources in the Con Edison Restoration Plan

**Background:**

There are already a number of comprehensive reliability requirements established by the NYS Reliability Council (NYSRC) that require the NYISO to develop and maintain a NYCA System Restoration Plan (SRP) that provides assurance that the NYCA system will be restored in a safe and orderly manner and as promptly as reasonable possible following a major or total blackout. The NYSRC also requires that Each *Transmission Owner* shall establish and maintain a restoration plan that shall be coordinated with the restoration plans of other *Transmission Owners* and shall be part of the NYCA System Restoration Plan. Lastly, the NYSRC requires that the NYISO facilitate the participation of black start capable resources for the Con Edison Restoration Plan.

a. Annual Review and Update of Restoration Plan

Current NYSRC reliability rules already provide for an annual review and update of the NYISO system restoration plan. This review process would provide the framework for the NYISO to analyze the impact of changes in the NYCA resource mix on the system restoration plan and make necessary changes on an ongoing basis. [90]

b. Coordination of NYISO and Transmission Owner Restoration Plans

Current NYSRC reliability rules already provide for coordination of NYISO and Transmission Owner Restoration plans. This coordination will continue to occur in the future and enable collective assessment of the impact of changes in the NYCA resource mix on the system restoration plan.

c. Facilitate Participation of Resources in the Con Edison Restoration Plan

The NYISO will continue to coordinate participation of resources in the Con Edison system restoration plan.

## 7. Voltage Support

Potential Reliability Gap # 7: The NYISO may be challenged to meet NERC, NPCC, and NYSRC voltage performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 7: The NYISO will continue to study voltage performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Study voltage performance in long-term planning timeframe (RNA)
b. Study voltage performance in short-term planning timeframe (Operating Studies/Limits)
c. Investigate the potential for new resource types to supply reactive capability

**Background:**

The provision of voltage support will potentially be impacted in several ways by the prospective changes in the NYISO resource mix. First, with fewer thermal units on line and more output provided by asynchronous resources it may be necessary to at times rely on asynchronous resources to provide voltage support.

Second as energy prices fall during the peak solar hours and at times when wind generation output is high, it will become increasingly necessary to commit thermal resources specifically to provide voltage support, because few thermal resources will be committed based on economics during some periods of the day.

90 The rule can be found in the NYSRC, Reliability Rules and Compliance Manual, April 11, 2019 section 2B2B pp. 26-27 Transmission System Planning Assessments.

Third, low energy prices will make it very expensive to commit thermal generation at minimum load to provide voltage support, with the result that thermal resources committed to provide voltage support will incur large losses on their minimum load output.

With respect to the first change, the potential need for the NYISO to rely more on voltage support provided by asynchronous resources is largely covered by FERC Order No. 827 requirements and the changes in the NYISO large and small generator interconnection agreements that were approved in FERC Docket ER17-61. In addition, the NYISO will assess the need for models, perhaps built into the day-ahead market, to evaluate the need to commit resources for voltage support, rather than continuing to rely on occasional commitments in real-time as is done today.

While FERC Order No. 827 requirements should largely address near term changes in NYISO voltage support needs, the California ISO's experience with operations with high levels of intermittent resource output caused it to include some additional requirements in its Order No. 827 compliance filing, as permitted by the FERC order. These requirements were included in ER17-490. One of these requirements was a prohibition on resources disabling voltage regulation controls when the resource is in operation, without the permission of the ISO. As the NYISO resource mix evolves over time, the NYISO will continue to evaluate the need for rules enabling the supply of voltage support from a wider range of resources or under a wider range of conditions in New York.

With respect to the second change, with less need to commit thermal resources to meet energy demand, and a likely higher cost of committing these resources out of market to provide voltage support, it will become more important to take account of voltage support needs in the day-ahead market solution. Moreover, because voltage support needs are local, the NYISO will need voltage support within specific narrow regions, not necessarily at the locations at which resources able to provide reactive power without incurring substantial commitment costs may be located. Hence, another set of changes the NYISO might implement to better meet these reliability needs would be to model commitments for voltage support in the day-ahead market, so that commitments of other resources would be made taking into account the output and reserves of resources that would be committed to provide voltage support.[91]

A consequence of the third change is that the NYISO may need to consider changes to its compensation design for voltage support to incent the development of resources able to meet New York voltage support needs at lower cost. Uplift payments to thermal units committed out of merit to provide voltage support do not provide a price signal for the development of resources able to provide voltage support at lower cost

91 The development of such a process would not be simple, as it should not only commit resources at least-cost but also avoid distorting the bidding incentives of resources committed for voltage support.

and these uplift payments have the potential to distort the energy and reserve offer prices of thermal resources able to provide voltage support. Hence, in a longer time frame the NYISO may find it desirable to eliminate the current compensation design for voltage support in which all resources receive payments based on accounting allocations of voltage support related costs and shift to a design that would better support competition among a variety of resource types that would be able to provide voltage support. These changes in the compensation design might be accompanied by the use of the planning process to identify the potential to meet voltage support needs at lower cost through installation of more voltage control devices.

## 8. Frequency Response

Potential Reliability Gap # 8: The NYISO may be challenged to meet NERC, NPCC, and NYSRC frequency performance requirements for a power system with high levels of intermittent generation.

NYISO Plan for Gap # 8: The NYISO will continue to study frequency performance in both the long-term planning and short-term operating timeframes and implement necessary operational and market changes in order to maintain acceptable control performance. Such changes are detailed in the following section and include:

a. Study frequency performance in short-term planning timeframe (Operating Studies/Limits)
b. Investigate the potential for new resource types to supply frequency response capability

**Background:**

The NYISO's frequency response obligations will be determined by NERC, reflecting changes in the resource mix across the eastern interconnection. Various NERC studies indicate that frequency response will become more of a reliability issues as less thermal generation is on line. The NYISO will likely want to anticipate these requirements. Some of the performance factors that the NYISO will need to review are the potential need to commit generation to meet NERC requirements, rules limiting the circumstances in which plant level controls on synchronous generators can be set to override frequency response (and perhaps requiring notification of the NYISO when plants are operating in this mode), modeling the output range in which synchronous resources can provide governor response, introduce frequency response performance requirements, develop NYISO systems that model the amount of available frequency response and adjust dispatch and commitment to meet NERC targets.

The NYISO's Order No. 842 Compliance filing addresses near term needs for frequency response from both generation and storage resources such as batteries.[92]

92 See NYISO filing in FERC Docket ER18-1620`

## 9. Maintain Resource Adequacy

Potential Reliability Gap # 9: The NYISO may be challenged to maintain acceptable levels of resource adequacy.

NYISO Plan for Gap # 9: The NYISO will continue to monitor resource supply capability relative to targets (IRM) for the both the long-term planning and short-term operating timeframes and implement necessary operational and market changes. Such changes are detailed in the following section and include:

a. Monitor supply relative to LOLE in long-term planning timeframe (RNA)
b. Monitor supply relative to IRM in shorter-term planning timeframe (ICAP Market)
c. Ensure reliability operating characteristics

### Background:

Beyond the time frame of the operating day, the NYISO will need to ensure that there are appropriate financial incentives for investment in resources able to provide balancing services. These investment incentives could in principle be provided through capacity market or energy market incentives but there are a number of practical issues with both approaches that will need to be considered. First, assessment of reliability needs will become more complex as the level of thermal generation is reduced and replaced with the output of intermittent resources and storage. Second, the determination of capacity resource requirements, such as minimum output duration, will become more complex as the level of intermittent resource output and reliance on energy limited storage resource increases. Third, setting requirements for and incenting capacity resource performance will become more difficult as the need for flexible capacity increases. Each of these changes is discussed briefly below.

#### Reliability Needs

When intermittent resources participate in the capacity market, they result in an economic displacement in the capacity market of the need for traditional resources to the extent the intermittent resources are assigned capacity value. As increasing amounts of intermittent resources are added to the system, their incremental capacity value and hence their ability to displace other resources should be expected to decline due to the common operating characteristics of the intermittent resources and their incremental contribution to reliability in meeting system load requirements. For example, large additions of solar resources may result in the shifting of the observed net peak load (load net of intermittent resource output) into evening hours when solar resources generate little or no output. Changes in the makeup of the resource fleet and the consumption patterns of electricity will require the NYISO to evaluate whether resource adequacy needs, and resource capacity values, continue to be defined by heat wave driven summer peak loads, or will need to shift to resource adequacy needs in alternative situations. The NYISO will need to continue to evaluate each resource's contribution to reliability to ensure the NYISO capacity market is not overstating the incremental capacity value of particular types of resources, leading to an inaccurate displacement in the capacity market of resources that are needed to maintain reliability.

As the NYISO resource mix evolves towards greater reliance on intermittent resource output and energy limited storage resources, assessment of the need for thermal capacity to meet reliability targets will require assessment of ramp needs and energy balance. With respect to ramp needs, the California ISO projects minute by minute future ramp needs, based on historical profiles and future resource mix, as part of its resource adequacy needs assessment. The California ISO analysis also projects the distribution of the maximum daily 3-hour ramp and the distribution of the secondary net load ramp.[93] Assessing the frequency and seasonal pattern for maximum ramps is important in evaluating the ability of the resource mix to meet the ramps. As the level of resource output in New York rises, the NYISO's process for setting the LCR and IRM may need to take account of these ramp capability needs. This would require modeling resource ramp capability and taking account of resource limits impacting the availability of ramp. Some resources may have use limits such as start limits, energy or emission limits, which constrain how often they will be able to provide ramp. There may also be a seasonal pattern to the availability of some resources,[94] which may also limit their value in meeting peak 3 hour ramps during some times of year. In addition, to the extent storage resources are used to provide capacity, and hence displace thermal generation, the NYISO's process for setting the IRM and LCR will need to take account of energy limits over the operating day, and potentially over multiple days.

Accounting for ramp needs and energy limits appears likely to materially impact the kind of analysis that is required to set the LCR and IRM and these changes will become larger as ramp needs and energy limits increase over time.

#### Resource Requirements

The increasing importance of ramp capability and energy limits in reliably meeting NYISO load will impact many requirements for capacity resources used to balance net load, such as ramp rates, notification and start-up times, minimum load levels, minimum run times, number of starts per day, number of hours the resource can sustain output, seasonal and time of day availability. Setting these requirements will become more complex, not only because of the complexity of modeling how these characteristics impact the IRM and LCR, but also because the need for particular characteristics from incremental capacity

93 See, for example, California ISO, Final Flexible Capacity Needs Assessment for 2020, May 15, 2019 Pp. 12-14

94 This could be the case for demand response based on curtailing load, which might only be consuming power during some times of the year.

resources depends on the aggregate characteristics of the capacity resources that will be used to meet the IRM.

### Financial Performance Incentives

The shortage pricing design of the NYISO real-time market should provide a sound framework that can be used to incent the development, investment in, and performance of resources able to balance load and generation in the time frame of the real-time dispatch. The NYISO design in which the scheduling of energy and ancillary services is co-optimized in the real-time dispatch should be effective both in providing balancing and in sending efficient price signals. However, as observed above there is a potential for the structure of the subsidies provided to low emission resources to produce such negative real-time prices that the effectiveness of real-time pricing incentives in the NYISO energy market is greatly diminished by the prevalence of uneconomic real-time commitments and widespread real-time bid production cost guarantee payments. In addition, if a material amount of intermittent resources operate under contracts whose subsidy design incents them to offer supply at extremely negative prices, the resulting extreme level of real-time price volatility could discourage participation the NYISO's real-time dispatch.

Another approach to incenting investment in flexible capacity would be to include flexible capacity requirements in the NYISO capacity market. The California ISO implemented an initial flexible capacity requirement in November 2014, covering the 2015 capacity year.[95] In June 2015, the California ISO began its effort to develop a "durable" flexible capacity requirement with an issue paper identifying the need to refine the initial design to address the need for additional ramping speed to meet rising one-hour ramps and the need for downward flexible capacity.[96] The development of the flexible capacity requirement continued into 2018 with the publication of the Second Revised Flexible Capacity Framework in April 27, 2018.[97] By 2018, the California ISO's view of its flexibility needs had evolved towards concerns with reliance on slow starting generation with long minimum run times and high minimum operating points.[98] The 2018 design document provided for the procurement of three distinct types of flexible capacity, 5-minute flexible, 15-minute flexible and day-ahead load shaping capacity.[99] The effort was suspended in July

95 The California ISO's effort to develop a flexible capacity requirement began in December 2012 with the straw proposal for the initial flexible capacity requirement that was filed with FERC on August 1, 2014 in FERC Docket ER14-2574 and implemented beginning November 1, 2014 to cover the 2015 capacity year.

96 See California ISO, Reliability Services Initiative – Phase 2 and Flexible Resource Adequacy Criteria and Must Offer Obligation – Phase 2: Issue Paper," June 25, 2015.

97 By 2018 the California ISO was no longer concerned with the need for downward ramp as more intermittent resources began submitting economic offers that allowed them to be dispatched down (likely a result in changes in the structure of the subsidies in utility RPS contracts that were intended to incent participation in the California ISO's economic dispatch).

98 See California ISO, Second Revised Flexible Capacity Framework, April 27, 2018, p. 3

99 See California ISO, Second Revised Flexible Capacity Framework, April 27, 2018, p. 4

2018, however, in part because of delays in the timing for developing changes to the California ISO day-ahead market.

The California ISO's experience with this resource adequacy design illustrates how complex such a capacity market approach would need to be if it were relied upon to incent investment in the kind of resources needed to most effectively and efficiently balance variations in intermittent resource output. In particular, the flexibility provided by a resource depends not only on its physical characteristics such as ramp rate, start-time, minimum load level, minimum run time, minimum down times, daily, monthly and annual start limits, energy limits, and emission limits, but also on its offer prices and parameters. Moreover, there is not a single type of flexibility that is needed but rather flexibility is needed in a variety of time frames that might be provided by different types of resources, and the amount of flexible capacity of a given type that is needed depends in part on the characteristics of all of the other capacity.

These considerations will make it very difficult to specify and meet resource flexibility needs through capacity market requirements, difficult for load serving entities to procure through bilateral contracting if they must assemble a portfolio of resources meeting a number of different capacity requirements, and difficult for the NYISO to clear a demand curve. The complexities of managing such a procurement process for multiple flexibility capacity attributes have apparently been a consideration in the California Public Utilities Commission seeking to shift to some kind of central procurement mechanism, which has raised additional design and market questions.

In California, the flexible capacity requirement has been non-binding despite the California ISO's concerns with the availability of sufficient flexible capacity and the California ISO has been engaged for several years in an ongoing review of changes to the flexible capacity requirement to better focus the requirement on procuring the kind of capabilities the California ISO needs to balance load and generation with a high level of intermittent resource output.

## 10. Ability to Manage Supply Resource Outage Schedules

Potential Reliability Gap # 10: The NYISO may be challenged to manage supply resource maintenance outage scheduling.

NYISO Plan for Gap # 10: The NYISO will continue to monitor its procedures for supply resource outage schedule to determine whether additional operational and/or market changes should be implemented to help maintain operating capability targets throughout the year.

Background:

The NYISO will continue to play a role in coordination generation and transmission outages and will develop load and reliability forecasts that will assist generation and transmission owners in scheduling both long and short-term outages in periods in which they are less likely to adversely impact reliability.

Increases in intermittent resource output may lead to changes in the seasonal pattern of net load variations, making it more difficult for generation owners and the NYISO to schedule generation maintenance at times when the capacity is unlikely to be needed. This has already been happening in the MISO, with the result that the MISO has run into generation shortages during what are normally considered to be off peak portions of the year. This has led the MISO to make changes in its generation outages scheduling process with the dual goal of better coordinating long-term outages and providing better information to generation owners on windows for scheduling short-term outages.[100]

Pay for performance capacity market designs can potentially contribute to improved outage scheduling outcomes by incenting capacity suppliers to avoid outages during reserve shortages, but these designs only take into account capacity needs, they do not reflect resource needed to provide other essential reliability services within a local area, such as voltage support, frequency response, or transmission security. In addition, if periods of potential capacity shortage are a result of a combination of variations in intermittent resource output and the outage schedules of other capacity suppliers, individual market participants may depend on the ISO to coordinate outages in a manner that enables the supplier to schedule outages in periods that reduce the risk of pay for performance penalties.

It is important to recognize that it will not be possible to maintain reliability simply by requiring that all outages be scheduled years in advance as there will be forced outages and other changes in conditions that will never be predictable in such a time frame. Hence, there needs to be a design that achieves several distinct goals for different kinds of resources and outages. First, for resources with very long outages that must be scheduled well in advance and have substantial impacts on the supply balance, such as nuclear refueling outages, a long-term scheduling process will be needed. Second, as the MISO has found, there also needs to be a short-run scheduling process for outages with shorter durations and whose need cannot be predicted far in advance. In addition to evaluating the reliability impact of proposed short-term outages and perhaps implementing additional rules to govern their scheduling, the NYISO may want to assess the MISO's design for providing information to market participants on the projected resource balance over future periods that would be impacted by scheduled outages so that market participants can try to shift outages into favorable period.

100 See MISO January 30, 2019 filing in FERC Docket ER19-915.

Third, the NYISO could consider whether there are changes to its current processes that would better facilitate short-run scheduling of short outages to take advantage of favorable (i.e. low net load) weather conditions (similar to the process for the scheduling of short-term transmission outages to take advantage of favorable conditions).

Fourth, the relative importance of energy and capacity market revenues is important in providing incentives for generation owners to not only schedule outages as permitted by the NYISO but also to complete the outage as quickly as is feasible. If almost all resource revenues are earned in the capacity market and the resource is insulated from capacity market penalties if it schedules the outage sufficiently far in advance, the resource operator will not have efficient incentives to minimize outage length. This will become more of a concern as the level of intermittent resource output rises and the predictability of net load declines as long outages can contribute to reliability problems, even if they are scheduled long in advance if conditions change.

# Appendix C: Revenue Analysis Details

This appendix provides the assumptions used in the revenue analysis described in the Revenue Sufficiency With and Without Carbon Pricing section Figure 7 as well as in the left most bar of Figure 8 and Figure 9.

We use a virtual dispatch model to analyze the composition of market revenues under NYISO's current market design. This model assumes that each resource is a price-taker and has no effect on market prices. Given each resource's operational constraints and costs, the model optimally schedules commitment and dispatch based on historical day-ahead and real-time prices for energy and ancillary services. Each resource is assumed to optimally schedule across grid services that it is capable of providing. We use this model to calculate capacity, energy, and ancillary services revenues using actual NYISO prices across four recent years (2015 through 2018).

We study eleven resources, which span a range of resource types that have recently entered the market (gas combined-cycle), are used as the reference technology for the capacity market (gas simple-cycle), or are the subject of key policies at the state or city level (gas steam, onshore and offshore wind, solar, and energy storage). In our view, these technologies will have important impacts on the NYISO supply mix in the near future, either as new entrants or as candidates for retirement. We selected locations for each technology based on a prevalence of existing and/or planned resources. We evaluated the following resources and locations:

- Gas Steam (Zone J)
- Gas Combined-Cycle (1x1 and 2x1 configurations in Zone G)
- Gas Simple-Cycle (5000F5 and LMS100 in Zone G)
- Onshore Wind (Zone C)
- Offshore Wind (Zone K)
- Solar (Zone C)
- Energy Storage (2-hr, 4-hr and 8-hr configurations in Zone J)

Based on the results of discussions with NYISO staff, our assumptions for the operational characteristics of fossil, renewable, and storage resources are shown below in Table  through Table respectively.

**Table 6: Fossil Resource Operational Parameters**

| Unit | Location | Capacity (MW) | Min Gen (MW) | Ramp Rate (MW/Min) | VOM ($/MWh) | Summer Heat Rate (MMBtu/MWh) | Cold StartUp Fuel (MMBtu/MW) | UCAP Capacity Rating (% of ICAP) |
|---|---|---|---|---|---|---|---|---|
| CT Frame SC-5000F | Zone G | 230 | 92 | >= 46 | $0.76 | 10.3 | 0.7 | 94% |
| GT (LMS100) | Zone G | 110 | 17 | >= 22 | $5.60 | 9.2 | 0.6 | 89% |
| CC 1x1 | Zone G | 340 | 168 | 40 | $1.07 | 6.95 | 4.4 | 97% |
| CC 2x1 | Zone G | 340 | 148 | 80 | $2.55 | 6.8 | 4.4 | 97% |
| Steam | Zone J | 400 | 125 | 4.5 | $8.50 | 11.0 | 10.0 | 94% |

Notes: Resource parameters were determined based on conversations with NYISO staff and a review of assumptions used in Analysis Group (2016) and Potomac Economics (2018), Net Revenue Analysis.

**Table 7: Renewable Operational Parameters**

| Unit | Location | Summer UCAP Rating (% of ICAP) | Winter UCAP Rating (% of ICAP) | Summer Capacity Factor | Winter Capacity Factor |
|---|---|---|---|---|---|
| Solar | Zone C | 39% | 1% | 21% | 14% |
| Onshore Wind | Zone C | 10% | 30% | 19% | 36% |
| Offshore Wind | Zone K | 38% | 38% | 33% | 52% |

Note: Capacity ratings from NYISO (2019e). Onshore Wind and Solar hourly production profiles are the same profiles used in NYISO (2017), National Renewable Energy Laboratory (2019a).

**Table 8: Storage Operational Parameters**

| Unit | Location | Roundtrip Efficiency | State of Charge Utilization | UCAP Rating (% of ICAP) |
|---|---|---|---|---|
| Storage (2-hour) | Zone J | 85% | 5-95% | 45% |
| Storage (4-hour) | Zone J | 85% | 5-95% | 90% |
| Storage (8-hour) | Zone J | 85% | 5-95% | 100% |

Note: Storage UCAP ratings assumed based on discussions with NYISO staff.

Based on these operational parameters, we imposed the following restrictions on market participation for each class of resources based on their operational characteristics:

- **Simple-Cycles:** 5000F commits in real-time, provides energy and 30-minute on-synchronous reserves only. LMS100 also commits in real-time, but provides all reserves and energy.
- **Combined-Cycles and Steamer:** commit in day ahead, provide regulation and synchronized reserves only.
- **Storage:** participates in both day ahead and real-time energy markets, assumed to provide synchronized reserves only. While storage is technically capable of providing regulation and non-synchronized reserves, we did not model participation in those services, as a relatively small amount of storage would saturate current market.

We also developed the following key market assumptions, described in Table  below.

**Table 9: Key Market Assumptions and Data Sources**

| Market Parameter | Assumption | Source |
|---|---|---|
| **Price of Natural Gas** | Zones C & G: Transco Z6 NY<br>Zone J & K: Iroquois Zone 2 | SNL |
| | | |
| **Environmental Costs** | | |
| CO2 (RGGI) | $4.68/ton from 2015-18. | RGGI Auctions |
| NOx | $2.83/ton from 2017-18 (winter)<br>$296.71/ton from 2016-2018 (summer) | SNL |
| SO2 | $2.22/ton from 2017-18. | SNL |
| | | |
| **Market Prices** | | |
| Capacity (ICAP) | Strip auction prices | NYISO |
| Energy | Hourly day-ahead and interval real-time prices | NYISO |
| Sync | Hourly day-ahead and interval real-time prices | NYISO |
| 10-Min NonSync | Hourly day-ahead and interval real-time prices | NYISO |
| 30-Min NonSync | Hourly day-ahead and interval real-time prices | NYISO |
| Regulation | Hourly day-ahead and interval real-time prices | NYISO |

The 2015-2018 average wholesale energy market revenues are presented for all evaluated resource types in Table 10.

**Table 10: Estimated Market Revenues by Resource and Service, 2015–2018 average ($/kW-year)**

| | Existing Steam Turbine Zone J | CC 1x1 Zone G | CC 2x1 Zone G | CT Frame (5000F5) Zone G | CT (SC LMS100) Zone G | Onshore Wind Zone C | Offshore Wind Zone K | Solar Zone C | Storage (2-hour) Zone J | Storage (4-hour) Zone J | Storage (8-hour) Zone J |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Capacity (MW) | 400 | 340 | 340 | 230 | 110 | 54 | 16 | 79 | 4 | 4 | 4 |
| Net Energy | $10 | $51 | $45 | $29 | $25 | $68 | $160 | $45 | $0 | $0 | $7 |
| Regulation | $0 | $12 | $13 | $0 | $7 | | | | | | |
| Sync | $1 | $9 | $11 | $0 | $18 | | | | $45 | $49 | $47 |
| 10-Min NonSync | | | | $0 | $5 | | | | | | |
| 30-Min NonSync | | | | $27 | $12 | | | | | | |
| *Net E&AS* | *$11* | *$72* | *$69* | *$56* | *$68* | *$68* | *$160* | *$45* | *$45* | *$49* | *$54* |
| Capacity | $92 | $73 | $73 | $71 | $65 | $3 | $15 | $7 | $44 | $88 | $97 |
| **Total Market Revenues** | **$102** | **$144** | **$142** | **$127** | **$132** | **$71** | **$175** | **$52** | **$89** | **$136** | **$151** |
| 2015-2018 Min/Max | $89 | $116 | $116 | $104 | $126 | $54 | $133 | $46 | $80 | $123 | $137 |
| 2015-2018 Max | $132 | $168 | $165 | $144 | $142 | $84 | $189 | $56 | $106 | $170 | $189 |
| Gross CONE | $105 | $249 | $220 | $161 | $230 | $260 | $662 | $173 | $190 | $282 | $399 |
| Net CONE | $94 | $177 | $151 | $105 | $163 | $192 | $502 | $128 | $145 | $233 | $345 |

Sources and Notes: Gross CONE for fossil and renewable resources from Potomac Economics (2018), Figure 14 and Figure A-106. Storage CONE calculated from capital costs in New York Department of Public Service (2018), Figure 15 (applying levelized fixed charge rate from Table 23). Net CONE calculated as Gross CONE less net energy and ancillary services revenues. For the existing Zone J steamer, average going forward costs from the Potomac Economics (2018) are shown in the row labeled "Gross CONE".

## Appendix D: GridSIM Modeling Analysis Details

The Brattle Group utilized the GridSIM capacity expansion model to analyze the builds, retirements, and market revenues under NYISO's current market design as well as in proposed designs through 2040. GridSIM simulates the optimal builds and retirements of capacity and optimal system operations to minimize system costs, subject to constraints on achieving required reserve margin targets, meeting load each hour, and achieving state clean energy policies and procurement mandates. The model outputs prices for energy, ancillary services, and capacity market products by zone, accounting for changes in the resource mix over time. The model also calculates required REC prices in order to incentivize sufficient renewable resources to meet state renewable energy mandates. Total revenues across all market products and REC must exceed a new resource's going forward costs for that resource to enter; existing resources will retire if revenues do not exceed going forward costs.

Brattle's simulations considered the following existing and new generation technologies in the following locations:

- Existing Biomass (Zones A-E, F, GHI, and K)
- Existing Coal (Zones A-E)
- New and Existing Natural Gas Combined Cycle (All zones)
- New and Existing Natural Gas Combustion Turbine (All zones, although no existing in F)
- Existing Natural Gas Steam Turbine (Zones A-E, GHI, J, and K)
- Existing Oil Steam Turbine (Zones A-E)
- Existing Oil Combustion Turbine (Zones J and K)
- Existing Kerosene (Zones GHI, J, and K)
- Existing Nuclear (Zones GHI retires in 2020 and 2021 and zones A-E)
- Existing Hydro (Zones A-E)
- Existing Pumped Storage (Zone F)
- Existing Imports and Exports (All zones)
- New and Existing Onshore Wind (Zones A-E)
- New Offshore Wind (Zones J and K)
- New and Existing Solar (wholesale and behind-the-meter; all zones although no new wholesale solar in zones J and K)
- New and Existing Energy Storage (2- and 4-hour; all zones)

Based on the results of discussions with NYISO staff, our assumptions for the operational characteristics of fossil, renewable, and storage resources are shown below in Table 1 and Table 2 respectively.

**Table 1: Fossil Operational Characteristics**

| Unit | Min Gen (% of ICAP) | VOM ($/MWh) | Heat Rate (MMBtu/MWh) | Startup Cost ($/ICAP MW/Start) | EFORd | Carbon Emissions (tons/MMBtu) |
|---|---|---|---|---|---|---|
| BioGen | 31% | $3.00 | 9.7 - 10.8 | 10.00 | 5% | 0.10 |
| Coal | 31% | $8.50 | 9.5 | 10.00 | 14% | 0.10 |
| Gas CC | 47% | $1.81 | 6.8 - 7.6 | 4.40 | 6% | 0.06 |
| Gas CT | 15% | $5.60 | 10.3 - 16.2 | 0.60 | 6% | 0.06 |
| Gas ST | 31% | $8.50 | 10.3 - 10.7 | 10.00 | 6% | 0.06 |
| Kerosene | 15% | $5.60 | 13.4 - 16.3 | 0.60 | 17% | 0.08 |
| Oil CT | 15% | $5.60 | 14.3 | 0.60 | 17% | 0.08 - 0.09 |
| Oil ST | 31% | $8.50 | 10.6 | 10.00 | 17% | 0.08 - 0.09 |

Sources and Notes: Carbon emissions from Carbon Dioxide Emissions Coefficients by Fuel, EIA. Heat rates for existing units derived from their respective values reported on Velocity Suite (2019). VOM and new unit heat rates from National Renewable Energy Laboratory 2019 Annual Technology Baseline (2019b). Minimum generation levels and startup costs provided by NYISO. EFORd values taken from the NYISO 2018 Comprehensive Review of Resource Adequacy. NYISO (2018e).

The following resource types were assumed capable of providing ancillary services:

- **Combustion Turbine:** Can provide energy, capacity, 10- and 30-minute spinning reserves
- **Combined-Cycles and Steamer:** Can provide energy, capacity, 10- and 30-minute spinning reserves, and regulation reserves
- **Energy Storage:** Can provide energy, capacity, 10- and 30-minute spinning reserves, and regulation reserves

Wind and solar hourly generation is modeled using zonal historical hourly profiles. The GridSIM analysis considers how the capacity value of these resource declines as more resources are added to the system, due to correlation in their output. Similarly, the analysis considers the declining marginal capacity value of short-duration storage as more of such resources are added to the system.

Resource cost assumptions are based on a variety of sources. Capital cost and fixed cost assumptions are based primarily on the 2019 NREL Annual Technology Baseline.[101] These costs are adjusted for Downstate resources per EIA data to account for the higher cost of developing resources Downstate.[102] New natural gas capital cost assumptions are consistent with the 2016 NYISO Demand Curve Reset (DCR) study and the 2019-2020 ICAP Demand Curve Model. Offshore wind costs are assumed $5,000/kW in 2018 based on a review of publicly available estimates of offshore wind costs in the US North Atlantic. The

101 See National Renewable Energy Laboratory (2019b)

102 See U.S. Energy Information Administration (2019)

modeled capital and fixed Operations and Maintenance (O&M) costs for zone F resources is shown in Table 2. Costs in other zones are scaled for other zones to account for anticipated differences in the cost of development.

Resource Cost of New Entry (CONE) is calculated as the Fixed O&M costs plus the Installed Capital Cost, levelized over the assumed lifetime of the plant at a discount rate of 8%. All resource going forward costs are reflected in the Fixed O&M costs.

**Table 2: Resource Costs in Zone F**

| Installed Capital Cost (Nominal $/kW) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** |
| **BioGen** | $4,043 | $4,097 | $4,147 | $4,368 | $4,349 | $4,410 | $4,473 | $4,556 | $4,639 | $4,720 | $4,798 | $4,868 | $4,946 |
| **Coal** | $4,098 | $4,161 | $4,224 | $4,289 | $4,355 | $4,421 | $4,491 | $4,580 | $4,669 | $4,758 | $4,843 | $4,920 | $5,005 |
| **Gas CC** | $1,784 | $1,806 | $1,829 | $1,852 | $1,875 | $1,884 | $1,907 | $1,937 | $1,968 | $1,999 | $2,032 | $2,061 | $2,095 |
| **Gas CT** | $901 | $917 | $942 | $950 | $961 | $961 | $972 | $985 | $1,000 | $1,014 | $1,030 | $1,043 | $1,060 |
| **Gas ST** | $4,098 | $4,161 | $4,224 | $4,289 | $4,355 | $4,421 | $4,491 | $4,580 | $4,669 | $4,758 | $4,843 | $4,920 | $5,005 |
| **Hydro** | $5,981 | $6,085 | $6,191 | $6,299 | $6,408 | $6,519 | $6,633 | $6,748 | $6,865 | $6,985 | $7,106 | $7,230 | $7,356 |
| **Kerosene** | $936 | $953 | $979 | $987 | $999 | $999 | $1,010 | $1,024 | $1,039 | $1,053 | $1,070 | $1,084 | $1,102 |
| **Nuclear** | $6,829 | $6,916 | $7,004 | $7,093 | $7,183 | $7,274 | $7,368 | $7,495 | $7,621 | $7,744 | $7,862 | $7,964 | $8,080 |
| **Oil CT** | $936 | $953 | $979 | $987 | $999 | $999 | $1,010 | $1,024 | $1,039 | $1,053 | $1,070 | $1,084 | $1,102 |
| **Oil ST** | $4,098 | $4,161 | $4,224 | $4,289 | $4,355 | $4,421 | $4,491 | $4,580 | $4,669 | $4,758 | $4,843 | $4,920 | $5,005 |
| **Pumped Storage** | $5,981 | $6,085 | $6,191 | $6,299 | $6,408 | $6,519 | $6,633 | $6,748 | $6,865 | $6,985 | $7,106 | $7,230 | $7,356 |
| **Solar** | $1,137 | $1,139 | $1,140 | $1,141 | $1,140 | $1,139 | $1,137 | $1,135 | $1,132 | $1,129 | $1,125 | $1,120 | $1,115 |
| **Solar - BTM** | $2,693 | $2,679 | $2,665 | $2,598 | $2,529 | $2,455 | $2,378 | $2,296 | $2,210 | $2,120 | $2,025 | $1,926 | $1,822 |
| **Storage ($/MWh)** | $379 | $360 | $341 | $330 | $319 | $308 | $296 | $283 | $280 | $276 | $271 | $267 | $262 |
| **Wind - Offshore** | $5,000 | $4,963 | $4,926 | $4,891 | $4,856 | $4,822 | $4,788 | $4,756 | $4,724 | $4,693 | $4,663 | $4,634 | $4,605 |
| **Wind - Onshore** | $1,614 | $1,618 | $1,621 | $1,624 | $1,626 | $1,627 | $1,628 | $1,629 | $1,628 | $1,627 | $1,626 | $1,623 | $1,620 |

| FOM (Nominal $/kW-year) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2018** | **2019** | **2020** | **2021** | **2022** | **2023** | **2024** | **2025** | **2026** | **2027** | **2028** | **2029** | **2030** |
| **BioGen** | $114 | $116 | $119 | $121 | $123 | $126 | $128 | $131 | $134 | $136 | $139 | $142 | $145 |
| **Coal** | $34 | $34 | $35 | $36 | $36 | $37 | $38 | $39 | $39 | $40 | $41 | $42 | $43 |
| **Gas CC** | $21 | $21 | $21 | $22 | $22 | $23 | $23 | $24 | $24 | $25 | $25 | $26 | $26 |
| **Gas CT** | $11 | $11 | $11 | $11 | $12 | $12 | $12 | $12 | $13 | $13 | $13 | $13 | $14 |
| **Gas ST** | $34 | $34 | $35 | $36 | $36 | $37 | $38 | $39 | $39 | $40 | $41 | $42 | $43 |
| **Hydro** | $31 | $32 | $32 | $33 | $34 | $34 | $35 | $36 | $36 | $37 | $38 | $39 | $39 |
| **Kerosene** | $12 | $13 | $13 | $13 | $14 | $14 | $14 | $14 | $15 | $15 | $15 | $16 | $16 |
| **Nuclear** | $157 | $160 | $163 | $167 | $170 | $173 | $177 | $180 | $184 | $188 | $192 | $195 | $199 |
| **Oil CT** | $12 | $13 | $13 | $13 | $14 | $14 | $14 | $14 | $15 | $15 | $15 | $16 | $16 |
| **Oil ST** | $34 | $34 | $35 | $36 | $36 | $37 | $38 | $39 | $39 | $40 | $41 | $42 | $43 |
| **Pumped Storage** | $31 | $32 | $32 | $33 | $34 | $34 | $35 | $36 | $36 | $37 | $38 | $39 | $39 |
| **Solar** | $14 | $13 | $13 | $14 | $13 | $13 | $13 | $13 | $13 | $13 | $13 | $13 | $13 |
| **Solar - BTM** | $22 | $21 | $21 | $21 | $20 | $20 | $19 | $18 | $18 | $17 | $16 | $15 | $15 |
| **Storage ($/kWh-yr)** | $9 | $9 | $9 | $8 | $8 | $8 | $7 | $7 | $7 | $7 | $7 | $7 | $7 |
| **Wind - Offshore** | $126 | $124 | $122 | $121 | $119 | $118 | $116 | $115 | $113 | $112 | $110 | $109 | $107 |
| **Wind - Onshore** | $44 | $45 | $45 | $46 | $46 | $47 | $47 | $48 | $48 | $49 | $49 | $50 | $50 |

Sources and Notes: Study to Establish New York Electricity Market ICAP Demand Curve Parameters, NYISO Demand Curve 2019-2020 Model, Analysis Group, Inc. (2016). Nuclear by the Numbers, Nuclear Energy Institute (2019). National Renewable Energy Laboratory. (2019b). World Nuclear News (2017). World Nuclear News (2017). U.S. Energy Information Administration (2019).

## References


Analysis Group (2016). Study to Establish New York Electricity Market ICAP Demand Curve Parameters. September 13, 2016.

Analysis Group (2019). Carbon-Pricing in NYISO Markets: Supplemental Analysis of Economic Impacts. April 23, 2019.

Edison Electric Institute (2016). Transmission Projects: At A Glance. December 2016. Posted at https://web.archive.org/web/20170125112000/http://www.eei.org/issuesandpolicy/transmission/Documents/Trans_Project_lowres_bookmarked.pdf

FERC (2017). Reference: Interconnection Process Improvements. December 7, 2017. Posted at https://nyisoviewer.etariff.biz/ViewerDocLibrary/FercOrders/20171207%20Ordr%20Accpt%20Intrcnnctn%20Queue%20Rfrms%20Flng_21090.pdf

Independent System Operator of New England (ISO-NE) (2019). Competitive Auctions with Sponsored Policy Resources (CASPR) Key Project. Accessed May 14, 2019. Posted at https://www.iso-ne.com/committees/key-projects/caspr/

Maggio, Dave (2017). Review of Summer 2018 ERCOT Market Performance webinar presented by Power Markets Today, October 31, 2018.

National Renewable Energy Laboratory (2018). The Potential for Energy Storage to Provide Peaking Capacity in California under Increased Penetration of Solar PV. Posted at https://www.nrel.gov/docs/fy18osti/70905.pdf

National Renewal Energy Laboratory (2019a). Offshore Wind hourly production profile from NREL WIND dataset.

National Renewable Energy Laboratory (2019b). 2019 Annual Technology Baseline. Accessed August 15, 2019.

NYISO (2016a) Proposed NYISO Installed Capacity Demand Curves for Capability Year 2017/2018 and Annual Update Methodology and Inputs For Capability Years 2018/2019, 2019/2020, and 2020/2021. September 15, 2016.

NYISO (2017). Congestion Assessment and Resource Integration Studies (CARIS) Database. D

NYISO (2016b). Re: Case 15-E-0302: Proceeding on Motion of the Commission to Implement a Large-Scale Renewable Program and a Clean Energy Standard. July 22, 2016. Posted at https://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={EE2A5C73-A89A-487B-B201-EFFDA10F9BA1}

NYISO (2018a). 2018 Power Trends, 2018.

NYISO (2018b). 2030 MAPS modeling (offshore wind scenario).

NYISO (2018c). IPPTF Carbon Pricing Proposal. December 7, 2018.

NYISO (2018d). Manual 2: Ancillary Services. April 2018.

NYISO (2018e) Comprehensive Area Review of Resource Adequacy: Covering the New York Control Area for the Study Period 2019 – 2023.

NYISO (2019a). 2019 Master Plan: Wholesale Markets for the Grid of the Future, April 2019 Draft. April 2019.

NYISO (2019b). 2019 Project Candidates. August 17, 2018.

NYISO (2019c). Comprehensive System Planning Process (CSPP). Accessed May 14, 2019.

NYISO (2019d). Management Committee material for agenda item 4. April 24, 2019. Accessed May 14, 2019.

NYISO (2019e). Manual 4: Installed Capacity Manual. March 2019. Accessed May 14.

NYISO (2019g). Power Trends 2019: Reliability and a Greener Grid. Accessed May 14.

NYISO (2019f). Performance Metrics Q1, 2018 through Q1, 2019. Accessed May 14, 2019.

NYSRC (2019) *Comments submitted by the New York State Reliability Council*, NYPSC Case No. 19-E-0530. October 16, 2019.

New York Department of Public Service (2016). Staff White Paper on Clean Energy Standard. January 25, 2016. Posted at http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7B930CE8E2-F2D8-404C-9E36-71A72123A89D%7D

New York Department of Public Service (2018). New York State Energy Storage Roadmap and Department of Public Service / New York State Energy Research and Development Authority Staff Recommendations. June 21, 2018. Posted at http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId=%7b2A1BFBC9-85B4-4DAE-BCAE-164B21B0DC3D%7d

New York Governor Press Office (2019). Governor Cuomo Announces Green New Deal Included in 2019 Executive Budget. January 17, 2019. Posted at https://www.governor.ny.gov/news/governor-cuomo-announces-green-new-deal-included-2019-executive-budget

New York State Energy Research and Development Authority (2018). New York State Greenhouse Gas Inventory: 1990–2015. September 2018. Posted at https://www.dec.ny.gov/docs/administration_pdf/nyserdaghg2015.pdf

New York State Energy Research and Development Authority (2019). Clean Energy Standard. 2019. Posted at https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Standard

New York State Senate (2019). Senate Bill S6599. June 18, 2019. Posted at https://www.nysenate.gov/legislation/bills/2019/s6599

Newell, Sam, Bruce Tsuchida, Michael Hagerty, Roger Lueken, and Tony Lee (2018). Analysis of a New York Carbon Charge (Updated). December 21, 2018.

Nuclear Energy Institute (2019). Nuclear by the Numbers. March 2019. Posted at https://www.nei.org/CorporateSite/media/filefolder/resources/fact-sheets/nuclear-by-the-numbers.pdf

U.S. Nuclear Regulatory Commission (2018). Backgrounder on Subsequent License Renewal. February 21, 2018. Posted at https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/subsequent-license-renewal.html

Patton, David (2017). Comments of David B. Patton, Ph.D. Regarding State Policies Affecting Eastern RTOs. April 24, 2017. Posted at https://www.ferc.gov/CalendarFiles/20170426150115-Patton,%20Potomac%20Economics.pdf

Potomac Economics (2016). 2015 State of the Market Report for the MISO Electricity Markets. June 2016. Posted at https://www.potomaceconomics.com/wp-content/uploads/2017/02/2015-State-of-the-Market-Report.pdf

Potomac Economics (2017). 2016 State of the Market Report for the New York ISO Markets. May 2017. Posted at https://www.potomaceconomics.com/wp-content/uploads/2017/05/NYISO_2016_SOM_Report_5-10-2017.pdf

Potomac Economics (2018). 2017 State of the Market Report for the New York ISO Markets. May 2018. Posted at https://www.potomaceconomics.com/wp-content/uploads/2018/06/NYISO-2017-SOM-Report-5-07-2018_final.pdf

Potomac Economics (2019a). 2018 State of the Market Report for the New York ISO Markets. May 2019. Posted at https://www.potomaceconomics.com/wp-content/uploads/2019/05/NYISO-2018-SOM-Report__Full-Report__5-8-2019_Final.pdf

Potomac Economics (2019b). Highlights of the 2018 State of the Market Report for the NYISO Markets. NYISO Business Issues Committee meeting May 13 2019. Posted at https://www.nyiso.com/documents/20142/6426548/2018%20NYISO%20SOM%20Report%20Presentation_for%20BIC.pdf/20600fe4-2967-532c-d6ec-382416e83abc

S&P Global Market Intelligence (2019). SNL Energy. Data downloaded November 2016 – April 2019.

U.S. Energy Information Administration (2019). Annual Energy Outlook 2019. Posted at https://www.eia.gov/outlooks/aeo/

Velocity Suite (2019). Unit Generation and Characteristics Dataset. Data downloaded June 2019.

World Nuclear News (2017). “Report outlines Ontario nuclear refurbishment benefits and risks.” November 22, 2017. Posted at http://www.world-nuclear-news.org/NP-Report-outlines-Ontario-nuclear-refurbishment-benefits-and-risks-2211177.html