Reliability and Market Considerations For A Grid In Transition

A Report by the
New York Independent System Operator

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Foreword

New York's electric power system is facing significant change over the next decade as policymakers promote renewable and storage resources to decarbonize the power sector. The NYISO must prepare its operations and markets to inform and guide this transition. This draft report provides a starting point for the discussions over how competitive energy markets must evolve in order to continue providing reliable, economically efficient electricity to all New Yorkers. As the grid transitions, the competitive markets' role in supporting reliability must also change.

To inform stakeholders, the NYISO is reviewing the reliability and market implications of the State's plans for a transition to cleaner energy resources. Although this report identifies several gaps that should be addressed, it also discusses the need for additional analyses to inform what types of market enhancements are needed given the rapid changes that are expected on the grid.

This draft report finds that the primary future challenge arises from the variability and unpredictability of wind and solar generation resources and the potentially large quantities of each. As the penetration of those technologies increases, the grid will need responsive and flexible resources that provide operating reserves to address expected and unexpected changes in net load. The grid will also need a substantial amount of installed reserve capacity available to serve load when wind and/or solar generation output is insufficient for periods that may range from minutes to several days. It is also important to examine the need for strategic transmission investments that enhance the operational flexibility of the grid and accommodate the integration of high levels of renewable generation.

Prices serve as a powerful control signal: they rise where and when necessary to attract and make available essential grid services, but will only be effective if the wholesale markets continue to reflect all grid reliability services needed. The key is to anticipate the need for existing and new grid reliability services and proactively evolve the wholesale market design to accomplish those needs.

This draft report identifies potential market design enhancements. The recommended market design approach emphasizes energy and ancillary services products and market pricing that are reflective of system conditions and operational needs.

This is the first step of many as we envision the grid of the future and this draft report creates a starting point for discussions with stakeholders. Stakeholder engagement will be key to develop these market design approaches and prepare for this future. We request that all written comments be provided by June 24, 2019. All comments will be posted on the NYISO's website. An updated report is expected to be available in late summer 2019.

Executive Summary

New York's electricity industry is transforming rapidly, from traditional, controllable fossil fuel generation to non-emitting, weather-dependent intermittent resources and distributed generation. These changes are driven primarily by state policies, but also by technological advancements that are expanding the possibilities of new resources and lowering their costs. New York State programs aim to serve 50% of load with energy generated from renewables by 2030. The Governor's proposed Green New Deal[1] would further mandate 100% clean power by 2040, increase the Clean Energy Standard mandate from 50% to 70% renewable energy by 2030, and provide a number of additional clean-energy mandates.[2]

The central question arising from these objectives will be how the wholesale energy market in New York can continue to provide pricing and investment signals necessary to reflect system needs and to attract and retain enough controllable and flexible resources to balance the electric system and provide grid services necessary for reliability. Moreover, from an operational perspective, it also becomes less clear how market-based operations can continue to maintain high levels of reliability at least-cost without the need for frequent and costly out-of-market interventions.

NYISO is actively studying all related important aspects of these questions in order to develop a successful plan to meet the future challenges expected to arise from a grid characterized with high levels of intermittent renewable resource and distributed generation penetration. 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. The key is to anticipate the needs for existing and new grid reliability services and proactively evolve the wholesale market design to accomplish those needs. Wholesale markets must continue to reflect all grid reliability services needed through defined products, with product pricing that reflects the marginal, cost to serve or forego (when supply is scarce) the reliability need. **Prices can thereby serve as a powerful control signal: they rise where and when necessary to attract and make available essential grid services.** Prices fall when and where the grid reliability service is not needed or when there is ample supply. In this way, and by fostering competition, prices help to maintain grid reliability at the lowest cost.

Our initial assessment of emerging reliability challenges indicates that the primary challenge arises from the variability and unpredictability of wind and solar generation. As the penetration of those technologies increases, the grid will likely need more load-following capability, and possibly more fast-

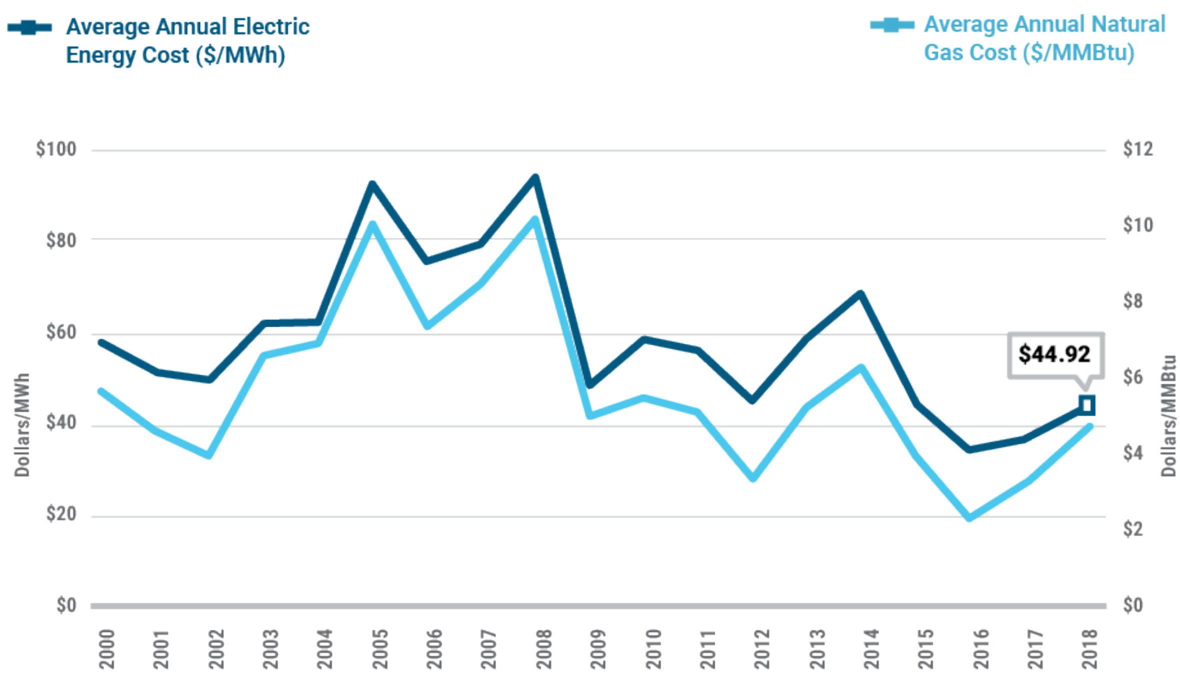
[1] See New York Governor Press Office (2019).

[2] See New York State Energy Research and Development Authority (2019).

response and flexible resources that provide operating reserves to address expected and unexpected changes in net load. The grid will also need a substantial amount of installed reserve capacity that is available to serve load when wind and/or solar generation output is insufficient for periods that may range from minutes to several days. Additionally, it will be important to examine the need for strategic transmission investments that enhance the operational flexibility of the grid and accommodate the integration of high levels of intermittent renewable generation.

To initiate developing a plan for evolving NYISO's markets and processes that can feed into the NYISO's *2019 Master Plan, Reliability and Markets for the Grid of the Future* (NYISO's Master Plan),[3] 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 need for changes to operations and planning processes necessary for maintaining reliability.

Figure 1: Annual Gas Costs and Electric Energy Prices: 2000-2018



Source: NYISO (2019g), Figure 21.

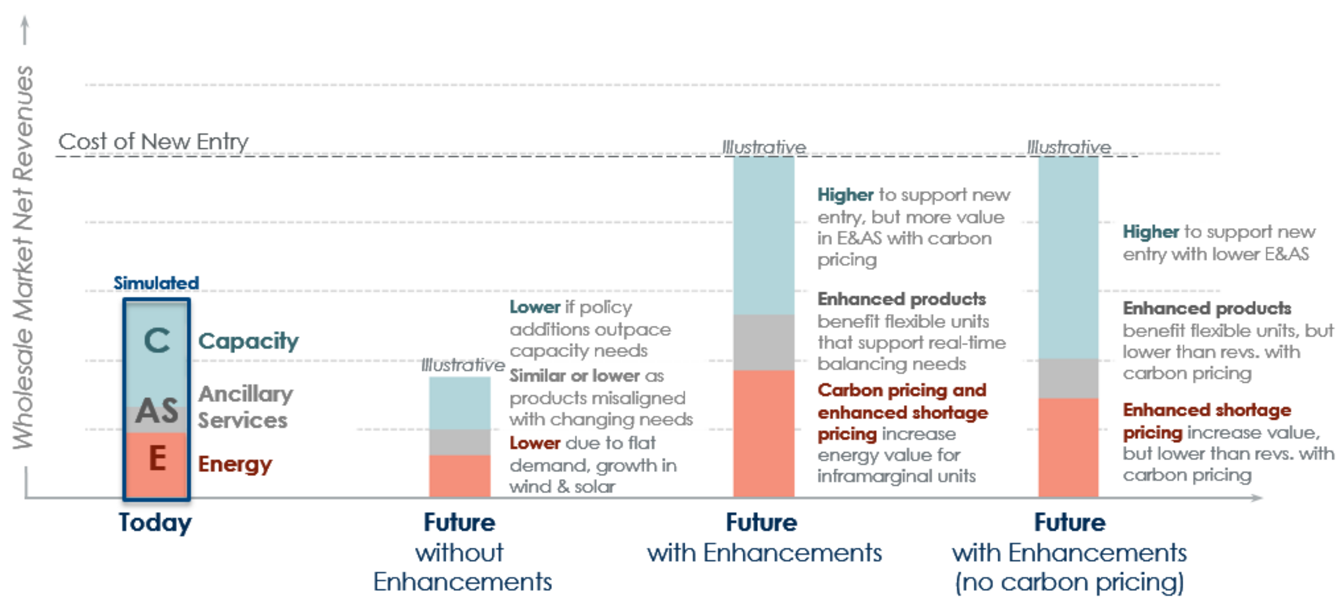
New York's markets have thus far maintained reliability and done so at competitive costs. Wholesale

[3] See NYISO (2019a).

electricity prices have tracked natural gas prices, the fuel most often used to produce electricity in New York, as shown in Figure 1. Indeed, no shortage of installed capacity or resources that provide necessary grid services currently exists.[4] We then assess the current markets' ability to meet future resource adequacy and operational needs, focusing on the appropriateness and completeness of product definitions for reliability services, price formation, and revenue adequacy. We next illustrate how revenue sources might evolve over time as market conditions and market designs evolve, and we outline further analysis that could quantify revenue streams under various scenarios.

Today, combined-cycle resources are generally the lowest net cost to build, the cleanest fossil generator to operate, and are likely to be the flexible resources replacing any older fossil resources needed to maintain reliable operations with high levels of intermittent renewable generation. Figure 2 below illustrates how revenues for a combined-cycle unit might evolve under these different scenarios. In a future without market design enhancements, the wholesale market revenues will not support the investment of new flexible generation needed to maintain grid reliability.

Figure 2: Illustrative Change in Revenues, 1x1 Gas Combined-Cycle (Assuming New Entry is Needed)



We have identified several potential market design enhancements, at various stages from investigation to development. Many are ongoing (Ongoing Effort), some are new efforts in prioritization (Under Consideration), and others would require further study and discussion with stakeholders before proposing any specific enhancements (Investigate).

[4] See Potomac (2015, 2016, 2018, 2019).

Table 1: Potential NYISO Market Design Enhancements

Market Enhancement Opportunity	Description	Status
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 Service markets.	Ongoing Effort
Define Reliability Challenges	Further analysis to better understand the reliability challenges caused by a changing resource mix	Ongoing Effort
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: Ancillary Services Shortage Pricing Constraint Specific Transmission Shortage Pricing Enhanced Fast Start Pricing	Ongoing Effort
Evaluate Load Forecasting Approach	Load forecasting may become more challenging as wind and solar deployments grow.	Ongoing Effort
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: More Granular Operating Reserves Reserve Enhancements for Constrained Areas Reserves for Resource Flexibility	Ongoing Effort
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: Consider introducing a third settlement between the Day Ahead Market (DAM) and the real-time market (RTM) Changes to DAM and/or RTM look-ahead time horizon or intervals	Investigate

Market Enhancement Opportunity	Description	Status
Capacity Market Opportunities		
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 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: Expanding Capacity Eligibility 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
Comprehensive Mitigation Review	A holistic evaluation of the BSM rules and methodology to evaluate whether the current framework will be adequate in a future with significant renewable resources and policy objectives that influence the capacity market.	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

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.

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 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 capacity market enhancements because real-time prices can reflect varied and dynamic operational needs better than any products that might be procured as "capacity."

This paper also reviews the NYISO's existing capacity market Buyer Side Mitigation (BSM) rules and finds that they may require further development in order to provide a comprehensive structure for administering and maintaining competitive wholesale energy markets in a state with ambitious public policy goals. Formulation of a practical but effective framework for administration of market mitigation measures is integral to the plan to address reliability and market considerations for a grid in transition. To achieve this, we review some options and possible changes to the mitigation measures. We plan to engage with stakeholders to formulate a comprehensive review of the BSM structure aimed at preserving market pricing levels that would allow for retention of existing market-based resources as well as entry of new market-based resources to meet reliability needs.

Background

Transforming the New York Power System and 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 energy markets in 1999, New York had a vertically integrated utility model. Economic efficiency concerns, as well an investment model that placed the burden of investment risk on ratepayers, led to the creation of the wholesale energy 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 markets also support retail competition, whereby competitive retailers buy supplies from the wholesale 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 market.

Wholesale 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 short-term operational reliability. The capacity markets work in tandem with the energy and ancillary services markets to achieve long-term resource adequacy objectives in the most cost-effective manner. Together these markets are supposed to 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 owners of new generation, to replace more than 7,000 MW of retirements while maintaining high operational reliability with limited out-of-market interventions.[5] The NYISO's markets have consistently been competitive, according to its external Market Monitoring Unit. 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.[6]

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.[7] 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.

In aggregate, the effect of these policies is to place new strains on the NYISO's ability, under the current market rules, to deliver reliable supply at competitive costs with the current market rules. Any enhancements to the market must take into account the myriad of policy drivers and their consequences for the wholesale market. Table 2 summarizes key Federal, state, and New York City policies, their objectives, and their implications for the NYISO wholesale market.

Table 2: Selected Major New York Policy Drivers

<table>
<tr><th>Policy Initiative</th><th>Policy Goal</th><th>Potential Wholesale Market Challenge</th></tr>
<tr><td colspan="3">Decarbonization Goals, Initiatives and State Clean Energy Mandates</td></tr>
<tr><td>Clean Energy Standard (40 x 30)</td><td>40% economy-wide GHG reductions from 1990 levels by 2030</td><td rowspan="5">More zero/negative price hours in energy market; maintaining appropriate investment signals, maintaining reliability with more intermittent renewable generation and demand-side impacts</td></tr>
<tr><td>Clean Energy Standard (80 x 50)</td><td>80% economy-wide GHG reductions from 1990 levels by 2050</td></tr>
<tr><td>Clean Energy Standard (Renewable Resources)</td><td>50% of electricity consumed in New York State generated from renewable resources by 2030. Retain upstate nuclear capacity.</td></tr>
<tr><td>Clean Energy Standard (ZECs)</td><td>Retain upstate nuclear units through 2029</td></tr>
<tr><td>Offshore Wind Development</td><td>Develop 2,400 MW of offshore wind capacity by 2030</td></tr>
</table>

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

6 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.

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

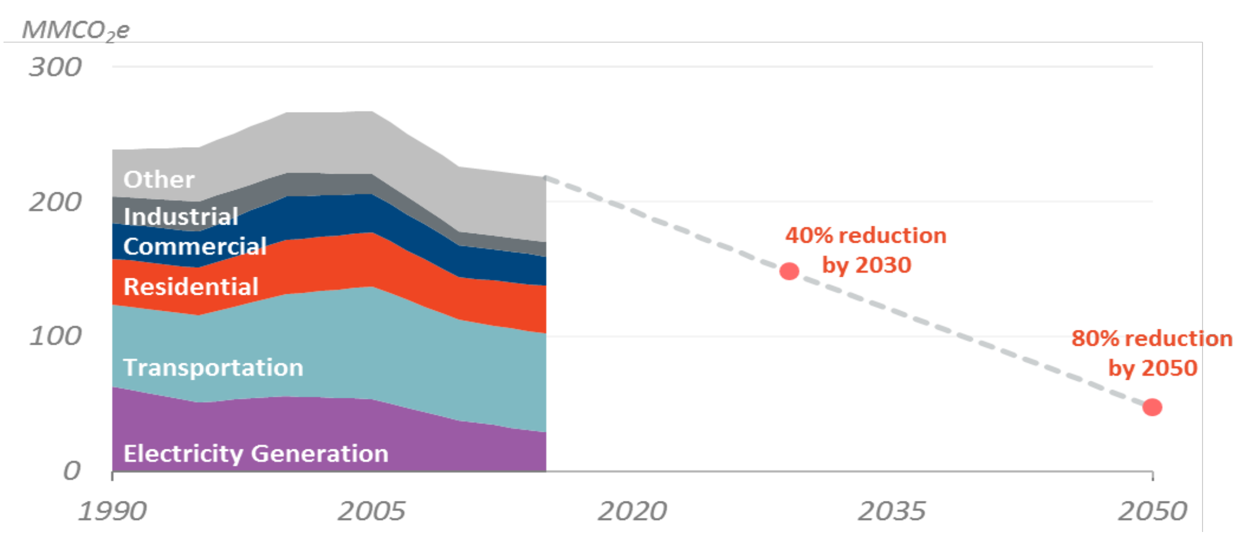
Policy Initiative	Policy Goal	Potential Wholesale Market Challenge
NY Green New Deal8 Proposed	70% of state's electricity needs from renewables by 2030. 100% carbon–free power grid and economy by 2040 along with technology specific goals. Increase offshore wind target to 9,000 MWs.	
Regional Greenhouse 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 CO2 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
State Energy Efficiency Mandate	600 trillion Btu statewide decrease from 2012 levels	Load forecasting accuracy. Smaller market over which to spread fixed costs
State Environmental Policies Directly Affecting Fossil Generation		
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. The NYISO is developing its Comprehensive Reliability Plan (CRP) for 2019-2028, which 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.
Support for Non-Traditional Resources		
Value of Distributed Energy Resources (VDER)	Transition from Net Metering (NEM) to VDER value stack compensation for DERs	Coordination between wholesale market signals and retail mechanisms to encourage distributed generation
Storage Deployment Mandate	1,500 MW by 2025, 3,000 MW by 2030	Updating market rules to enable storage to compete with other resources where they provide value to the grid
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 REC and ZEC payments into capacity auction

8 See New York Governor Press Office (2019).

Policy Initiative	Policy Goal	Potential Wholesale Market Challenge
Energy Storage Order	Require RTO tariff revisions to facilitate participation of energy storage in wholesale markets	Optimally dispatching storage and evaluating storage's resource adequacy value
Distributed Energy Resources (DER) NOPR	Require RTO tariff revisions to facilitate participation of aggregate distributed energy resources	Controlling and optimally scheduling aggregated DERs
Grid Resilience	Maintain grid resilience by retaining at-risk nuclear and coal units through out-of-market payments	Wholesale markets must be made robust enough to withstand out-of-market payments to subsidized resources

Across the slate of policies enumerated in Table 2, New York's economy-wide decarbonization 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 3 below illustrates New York State historical greenhouse gas emissions and a linear trajectory to meet the targeted reductions in 2030 and 2050. These policies will drive a transformational shift in coming years from the gas-fired power plants that provide more than one-third of New York's power electricity needs to considerably higher levels of non-emitting, weather-dependent intermittent resources such as solar and wind. Achieving 40% and 80% reductions of in-state Greenhouse Gas (GHG) emissions will likely require even more changes including substantial electrification to decarbonize 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 impacts today.

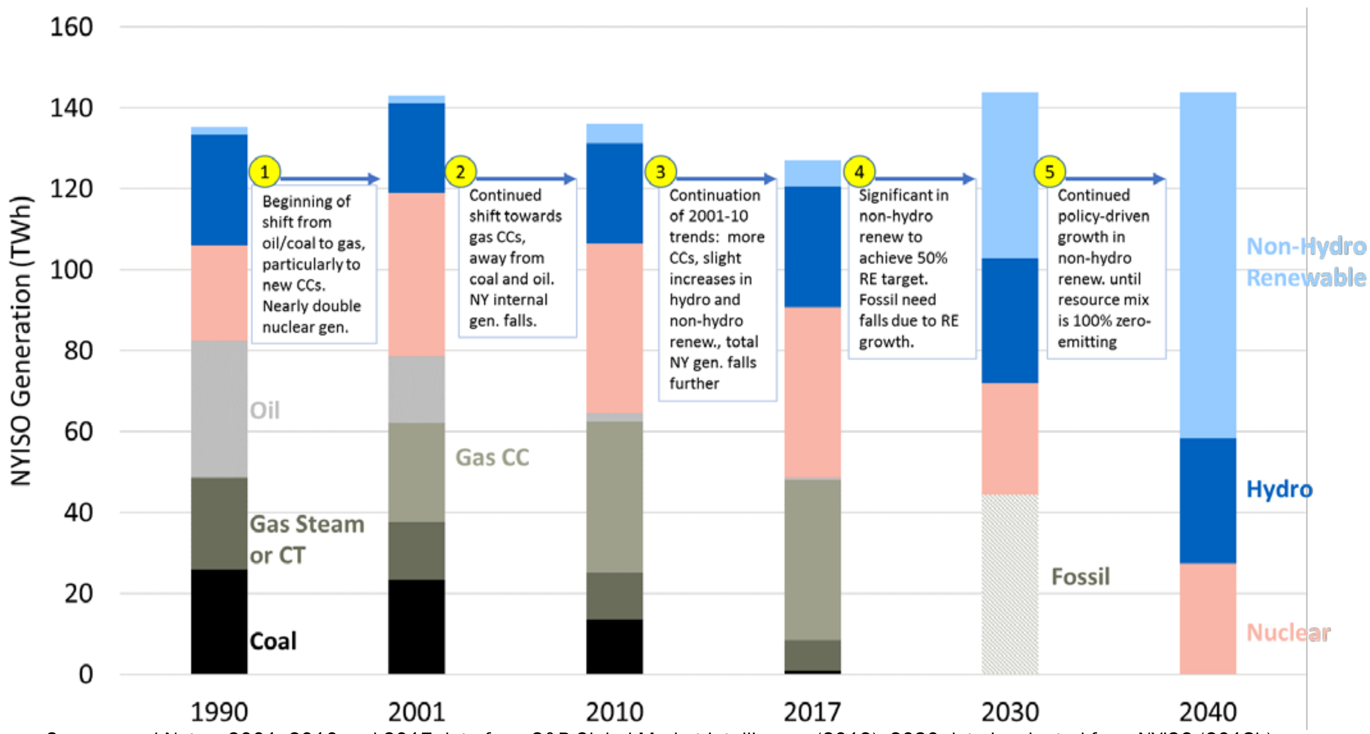
Figure 3: New York State Economy-Wide GHG Emissions History and Future Reduction Goals



Sources and Notes: New York State Energy Research and Development Authority (2018), analysis performed for NYISO by Brattle.

By 2030, carbon dioxide emission-free renewable and nuclear resources could provide 50% to 90% of New York's generation.[9] By 2040, the electric system may be nearly 100% carbon-neutral in order to support an increasingly electrified (and decarbonized) New York economy.[10]

Figure 4: Change in New York Supply, 1990 - 2040



Sources and Notes: 2001, 2010 and 2017 data from S&P Global Market Intelligence (2019). 2030 data is adapted from NYISO (2018b). 2040 shows assumed resource mix needed to achieve 100% zero-emissions goal.

Figure 4 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

9 50% assumes current Clean Energy Standard procurements (50% renewables by 2030) and retirement of all New York nuclear units at the expiration of the ZEC program in 2029. 90% assumes Clean Energy Standard increased to 70% and no nuclear unit retirements other than Indian Point; all nuclear units secure "Subsequent License Renewal" to remain online through 2049. See U.S. Nuclear Regulatory Commission (2018).

10 See New York Governor Press Office (2019).

market incentives (in both the wholesale electric 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.

The trends observed from 2010 to 2017 include continued decreases in 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 4 is the role of markets in achieving this transition. From 1990 to today New York faced large scale changes, emissions markets and wholesale electric markets, working together, 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 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. So, how can the wholesale markets continue to support grid reliability through this transition?

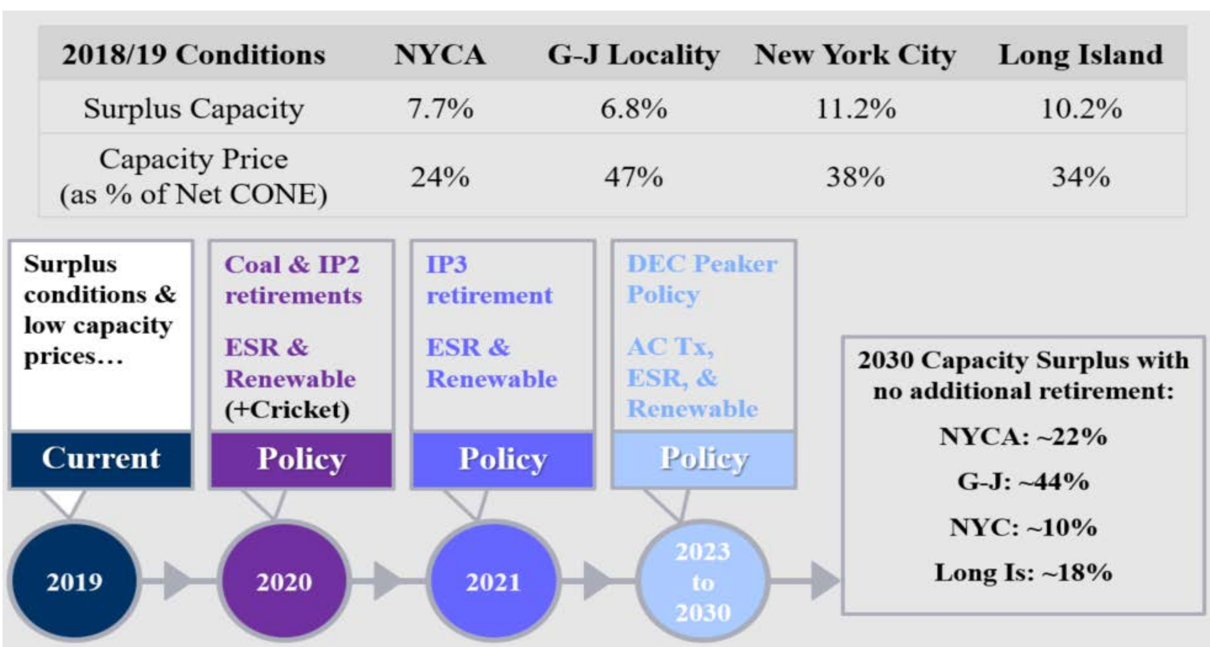
New Challenges in a Decarbonizing System

Nationwide, electric 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 select the more efficient or cost effective transmission solution that is eligible for cost allocation and cost recovery under the NYISO's tariffs. These planning processes support the reliability and efficiency of the electric grid and the ability of the electric grid to support public policy goals.

Moreover, the monumental shift in the generation mix portrayed above in Figure 4, 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 may not align well with the current wholesale market design. Additionally, as indicated in Figure 5 below, there may be a need for retirement of inflexible generation to support new intermittent renewable resources. Many of the new resources will be weather-dependent (*e.g.*, wind and solar resources), which creates 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 in turn places a greater emphasis on ancillary services and capacity market requirements and revenues to retain flexible and controllable resources to maintain reliable system operation. Absent a corresponding increase in capacity or ancillary service requirements and revenues or other wholesale market changes, investment signals for complementary resources may be insufficient to meet future reliability challenges.

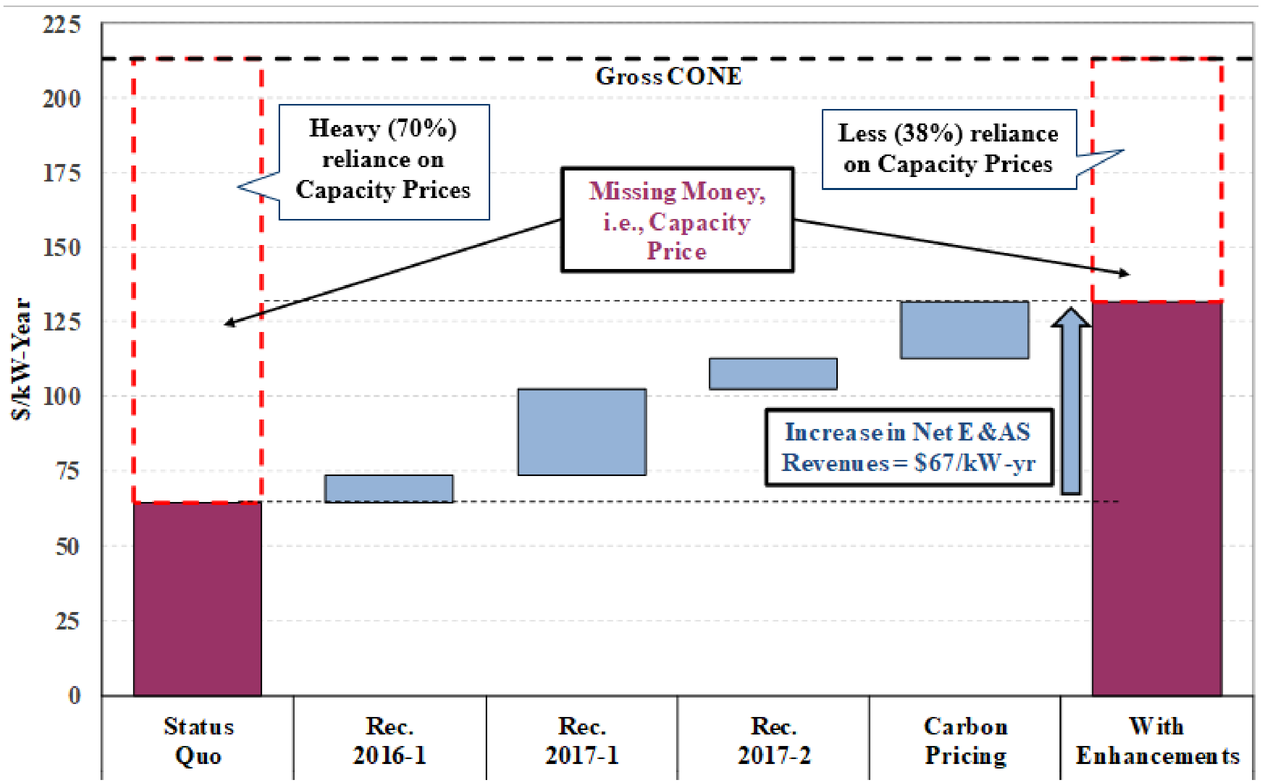
Figure 5: How Policies Stack Against Present Conditions



Source: Potomac Economics (2019), Highlights of the 2018 State of the Market Report for the NYISO Markets.

The wholesale market design will have to evolve to fully value all grid services needed to maintain reliability as the generation fleet changes. Figure 6 is an example of this provided by the NYISO's MMU. Ideally, the wholesale 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 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 market's ability to meet multiple objectives at least cost is especially important now, given the State's ambitions to transform the energy system.

Figure 6: Enhancing Incentives for Key Attributes



Source and Notes: Potomac Economics (2019), Highlights of the 2018 State of the Market Report for the NYISO Markets.
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.

Tuning the wholesale market design so it is up to this task will require proactive enhancements to the market that can recognize State objectives and the marginal value of the various, necessary grid reliability services. Some 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 must proactively anticipate reliability needs and design 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 and could challenge reliability. Not getting the rules in proactively would also miss the opportunity to create the appropriate investments signals.

Reliability Considerations

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.

Operational Challenges with Growing Reliance on Intermittent Generation

This section identifies a number of areas of potential future reliability gaps assuming a high level of intermittent resources and resources with limited energy operating in the New York Control Area (NYCA) and proposes recommendations to address the gaps identified.

The potential areas of future reliability gaps include the following:

1. Maintain Ability to Balance Load and Generation
2. Maintain 10-Minute Operating Reserves
3. Maintain Total 30-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 while balancing high output 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, which may include:

a. Increasing statewide regulation procurement requirements
b. Increasing statewide 10- and/or 30-minute operating reserve requirements
c. Investigating the need for separate regulation "up" and "down" service
d. Promoting more frequent interchange scheduling with neighboring regions
e. Improving the NYISO's Real-Time Energy Market Dispatch
f. Accounting for increased real-time load forecast uncertainty

2. Maintain 10-Minute Operating Reserves

Potential Reliability Gap #2: The NYISO may be challenged to schedule sufficient 10-minute operating reserves and meet NERC disturbance control performance requirements in response to variations in the levels of output from intermittent generation.

NYISO Plan for Gap #2: The NYISO will continue to track the resources capable of providing and offering 10-minute operating reserves and the applicable NERC Balancing Area Disturbance Control Standards. If necessary, the NYISO will develop and implement necessary operational and market changes in order to maintain acceptable control performance, which may include:

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

3. Maintain Total 30-Minute Operating Reserves

Potential Reliability Gap #3: The NYISO may be challenged to meet the NPCC Operating Reserve Standards requirements to not be deficient of 30-minute operating reserve for greater than four hours in response to longer-term variations in the levels of output from intermittent generation.

NYISO Plan for Gap 3: The NYISO will continue to track performance with respect to applicable NPCC Operating Reserve Standards; monitor Control Performance, reserve deficiencies, and the ability to re-establish reserves after a reserve shortage occurs. If necessary, the NYISO will develop necessary operational and market changes in order to maintain acceptable control performance, which may include:

a. Increasing statewide 30-minute reserve requirements
b. Promoting more frequent interchange scheduling with neighboring regions
c. Accounting for increased real-time load forecast uncertainty
d. Evaluating the sustainability requirements of 10-minute and 30-minute reserves

4. Maintain Ability to Meet Daily Energy Requirements

Potential Reliability Gap #4: The NYISO may be challenged to meet NERC Balancing Area Control

Performance Standards criteria when managing high output levels of intermittent resources and resources with limited energy to meet balancing energy requirements in real-time operations.

NYISO Plan for Gap #4: The NYISO will continue to track performance with respect to applicable NERC Balancing Area Control Performance Standards and operating reserve criteria. If necessary, the NYISO will develop and implement necessary operational and market changes in order to maintain acceptable control performance, which may include:

a. Developing new capability for operator management of limited energy supply resources
b. Increasing statewide 10- and/or 30-minute operating reserve requirements
c. Accounting for real-time load forecast and intermittent renewable uncertainty

5. Transmission Operations and Congestion Management

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

NYISO Plan for Gap #5: The NYISO will continue to track performance with respect to applicable NERC, NPCC, and NYSRC Transmission Operations Standards. If necessary, the NYISO will develop and implement necessary operational and market changes in order to maintain acceptable performance, which may include.

a. Increasing transmission facility constraint reliability margins
b. Increasing locational 10-minute spin and total operating reserve requirements
c. Increasing locational 30-minute operating reserve requirements
d. Investigating the need for a locational (zonal) ramping product
e. Accounting for increased real-time load forecast uncertainty
f. Evaluating the sustainability requirements of 10 minute and 30 minute reserves

6. Restoration and Black Start Capability

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

NYISO Plan for Gap #6: The NYISO will implement and monitor the effectiveness of established NERC and NYSRC Standards and procedures that require acceptable tools and processes for statewide and NYC restoration. NYISO will continue to review and test black start capability performance to ensure it can be maintained as system changes occur through time:

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

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 penetration levels of intermittent resources.

NYISO Plan for Gap #7: The NYISO will continue to study voltage performance in both the long-term planning and short-term operating timeframes. If necessary, the NYISO will develop and implement necessary operational and market changes in order to maintain acceptable control performance, which may include:

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

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 penetration levels of intermittent resources.

NYISO Plan for Gap #8: The NYISO will continue to study frequency performance in both the long-term planning and short-term operating timeframes. If necessary, the NYISO will develop and implement necessary operational and market changes in order to maintain acceptable control performance, which may include:

a. Study frequency performance in the long-term planning timeframe (RNA)
b. Study frequency performance in the short-term planning timeframe (Operating Studies/Limits)
c. Investigate the potential for new resource types to supply frequency response capability as new technologies seek participation in programs

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 (*e.g.,* total system reserve margin and IRM) for the both the long-term planning and short-term operating timeframes. If necessary, the NYISO will develop and implement necessary operational and market changes, which may include:

a. Monitor supply relative to LOLE in long-term planning timeframe (RNA)

b. Monitor supply relative to IRM in shorter-term planning timeframe (Installed Capacity (ICAP) Market)

c. Ensure generator operating characteristics are accurately modeled when evaluating resource adequacy and are appropriately accounted for in the ICAP market

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 scheduling to determine whether additional operational and/or market changes should be developed to help maintain operating capability targets throughout the year.

Planning Challenges with 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 upstate and northern regions to consumers downstate.

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 – even as statewide load decreases – 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 from upstate renewable resources to downstate load centers are necessary.

- Failure to expand transmission capabilities from upstate to downstate will 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 Clean Energy Standard goal of achieving 50% renewable energy generation by 2030 will be jeopardized because energy delivery from renewable resources to downstate load centers will be constrained.
- A robust and flexible transmission system will become even more essential if the state enacts proposed legislation to generate 70% renewable energy by 2030 and carbon neutral electricity supply by 2040.

The Challenge of Energy Usage Trends & Load Forecasting Challenges

Forecasting load and operating the bulk power system becomes more complex as additional as 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. This expansion should take into account the impacts to the bulk power system 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 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.

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, assess the reliability impacts of connecting a generator to the grid. If the NYISO identifies reliability issues, the interconnection study process identifies upgrades and estimates costs associated with those upgrades to allow the generator to interconnect reliably.

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, FERC accepted a comprehensive reform to the NYISO's interconnection processes[11] 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.

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11 See FERC (2017).

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 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 is developing proposed procedures and tariff revisions to implement these further process improvements.

In parallel with the above effort, the NYISO has developed compliance revisions in accordance with the directives of 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[12],

> **"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 integrate and improve its Comprehensive System Planning Process (CSPP)[13] 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

12 Edison Electric Institute (2016), p. iv.

13 See NYISO (2019c).

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

In 2019, the NYISO will make further improvements to its public policy process and propose changes to further integrate its planning for reliability, economic and public policy needs. The NYISO believes that considering reliability, economic and public policy planning needs under a single integrated process, will improve the planning process by allowing greater flexibility to respond to changing conditions and by fully recognizing the value of proposed projects that address multiple planning needs (reliability, economic, and/or public policy).

Assessing Investment Challenges and Revenue Adequacy

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.[14]

The NYISO supports reliability primarily through three complementary markets for energy, ancillary services, and capacity. Each addresses distinctive reliability needs, and each currently provides high enough prices to meet those needs. Prices are generally set at the highest offer that must be taken in order to meet the next MW of demand. When there is not enough supply available, prices can rise indicating supply shortages, which incents performance and helps support investment when and where resources are needed. Collectively, these three markets have provided enough revenue to attract and retain sufficient resources and to operate them reliably over the last twenty years.

A mechanism to maintain revenue adequacy for needed resources under equilibrium conditions exists in the NYISO's markets. As shown in the Figure 7 above, the revenues needed to maintain resources necessary to meet reliability criteria are provided through energy, ancillary services and capacity market payments. At equilibrium, total revenues equal cost of new entry. The entry of significant amounts of zero variable cost renewable resources may depress energy prices, but capacity revenues should increase to maintain revenue adequacy if capacity is needed. The capacity market is designed to perform such a function as it is structured to provide "missing money" for needed resources through a Demand Curve anchored by the revenue requirements of the Cost of New Entry (CONE) Unit under equilibrium conditions.

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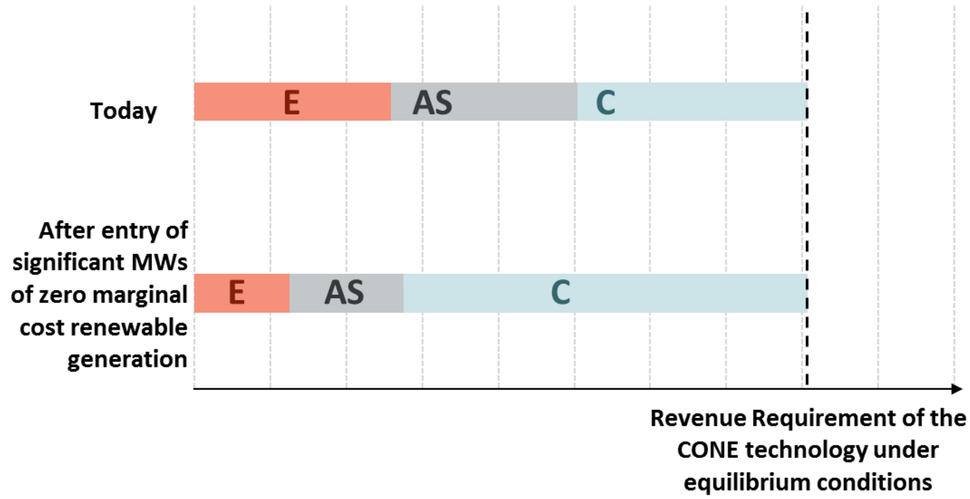
14 See NYISO (2018a), p. 17.

Figure 7: Illustration of the effect of zero marginal cost renewable generation entry on the capacity market "missing money"



Investment Challenges that increase in the Future

To attract needed merchant investment where generation owners continue to bear the investment and operational risk, NYISO's markets will have to provide opportunities for adequate revenues for energy, capacity, and necessary ancillary services. 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 to 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 profit from the shortage and 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 controllable, flexible resources that can support the integration of state-sponsored 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 below.

The shift towards decarbonization creates new risks for investors unlike other risks faced in the past and creates new challenges for the investability of NYISO's markets. However, these risks can be overcome through actions by the NYISO, New York policymakers, and the market. Below we outline three major challenges and potential solutions to each.

The Challenge of Lower and More Volatile Energy Prices

Growth in subsidized, zero variable cost generation will put downward pressure on prices, including zero or negative wholesale 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 may be 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, systemic 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 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, 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 last summer when generators demonstrated very low forced outages during the hottest week of the year.[15] 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. 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 Increased Regulatory Risk

With market outcomes increasingly driven by regulations and policies associated with decarbonization, regulatory risk rises. Regulatory risk is difficult for investors to manage efficiently, resulting in higher cost and lower reliability. Greater regulatory risk increases the value of the real option to wait for better or more information about the direction of the market as regulatory policies are implemented. In the meantime, a lack of investment to retain existing resources or attract new resources can result in reductions in resource adequacy or leave the system short of resources with sufficient flexibility to provide essential reliability services. As a result, prices will reflect the reliability challenges and become increasing volatile due to the lack of timely investment.

Reducing regulatory risk is primarily the responsibilities of state and federal policymakers. Policies should be predictable and consistent over time, in service of long-term stable goals such as New York's 80% economy-wide decarbonization by 2050.[16] Predictable and time-consistent policies reduce the value of the option to wait for better or additional information before making investment decisions, and makes planning for investment easier. Merchant investors benefit from policymakers reaffirming their commitment to the merchant investment model. For example, ERCOT has seen continued merchant investment, in part due to their longstanding commitment to letting the market work by allowing high prices, high congestion, and low reserve margins without intervention.

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 ensure they can earn near-term returns above levelized costs, with the expectation that returns will fall in the future as new, lower-cost

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15 Maggio, Dave (2017).

16 See Patton, David (2017).

technologies are developed.

To encourage merchant investment in technologies with rapidly declining costs, NYISO's product definitions and pricing should allow for higher prices such that required resources can recover investment costs by earning sufficient revenues in the short to medium term since a realistic expectation is that revenues will decline in the future. For example, capacity market pricing and the Net Cost of New Entry (Net CONE) may need to reflect declining future prices. Even if prices are allowed to be higher, price formation should still reflect underlying system needs and encourage market competition to drive prices to 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 depress prices in NYISO's markets, threatening the investability of the markets and, therefore, threatening reliability.

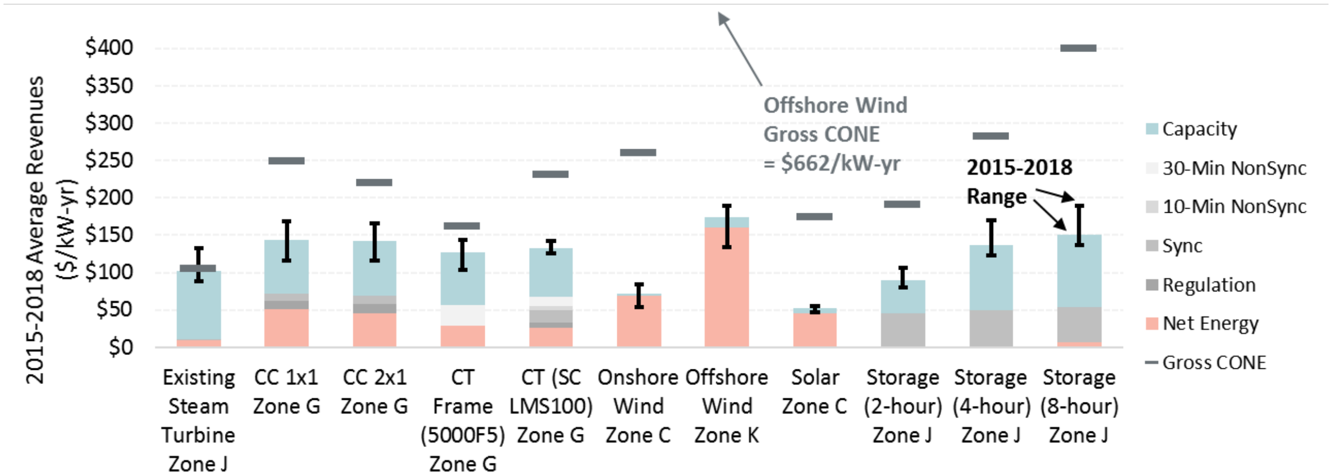
To provide a vision of how revenues may evolve in the future, we evaluate market revenues to several resource types under today's market design. We then *qualitatively* estimate how these revenues may change in the future with and without market design changes, including carbon pricing and additional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

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 battery storage. We evaluate 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 evaluate capacity revenues based on historical capacity prices in the respective capacity zones and each resource's NYISO-assigned, derated capacity value.[17] Further details on the assumed operating parameters for each technology can be found in the Appendix.

Figure 8 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. Detailed results can be found in the Appendix.

Figure 8: Estimated Market Revenues by Resource and Service, 2015–2018 average



Sources & 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.

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.

17 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 B: Revenue Analysis Details)

- **Gas-fired steam turbines** earn nearly all of their revenue from the capacity market, about 10% of revenues ($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-min non-synchronized reserves.
- **Wind and solar** resources earn nearly all of their wholesale 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 (RECs) in accordance with State public policy.
- **Battery 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.

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.[18] 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 baseload 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 needed new resources will be less than their cost of entry, even when the market is short the services needed to maintain reliability.

[18] 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.

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 • Higher price volatility driven by increased forecasting error due to unpredictable wind / solar output	 ▪ Prices rise with carbon pricing with fossil on margin ▪ Gas is likely the marginal resource most hours through 2030 ▪ When system approaches 100% carbon free, a carbon price will not increase energy prices as gas is never marginal ▪ Enhanced shortage pricing better reflects system conditions and customer value ▪ Engaging demand reduces frequency of zero/negative priced hours	 ▪ Prices rise due to enhanced shortage pricing and engaged demand-side ▪ Lack of carbon price somewhat limits increases in energy price
Ancillary Services	 • Prices likely similar to or lower than today • Prices fall if products misaligned with needs • Prices fall if storage procurements development outpaces A/S needs • Prices rise if other dispatchable units are online less, reducing availability to provide regulation and sync	 ▪ Enhanced products support reliable real-time operations ▪ 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 ▪ Price increases less than if carbon pricing adopted
Capacity	 • Prices fall if state renewable procurements and other climate policies outpace capacity needs • Prices rise if energy prices cause the Net CONE to rise • 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) ▪ 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 should 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 3 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 to energy, ancillary services, and capacity products

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 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, battery storage and gas-fired combined-cycles that typically emit less carbon than the marginal resource and can thus profit from higher energy prices. Additional market product and pricing enhancements may further increase revenues to flexible resources such as battery storage and gas peakers that provide grid services needed to balance intermittent renewable resources. Figure 9, 10, and 11 illustrate these changing market revenues at a conceptual level; further analysis is needed to refine and validate these findings.

Figure 9: Illustrative Change in Revenues, 1x1 Gas Combined-Cycle (Assuming New Entry is Needed)

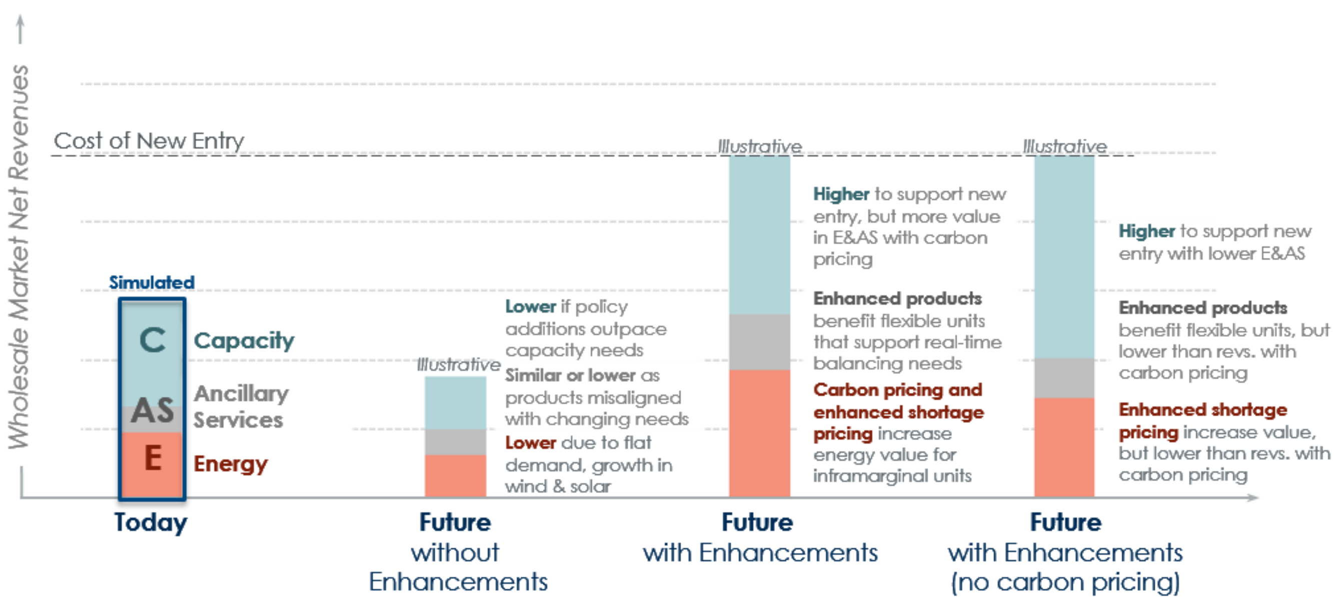


Figure 10: Illustrative Change in Revenues, Frame Gas Simple-Cycle (Assuming New Entry is Needed)

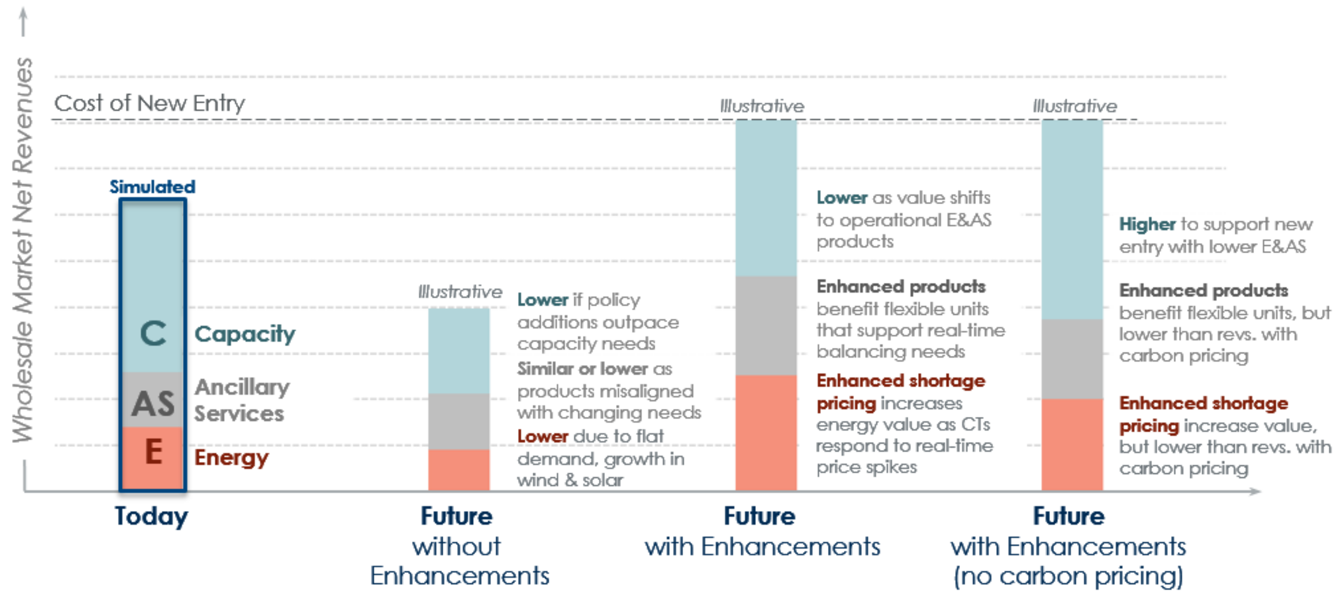
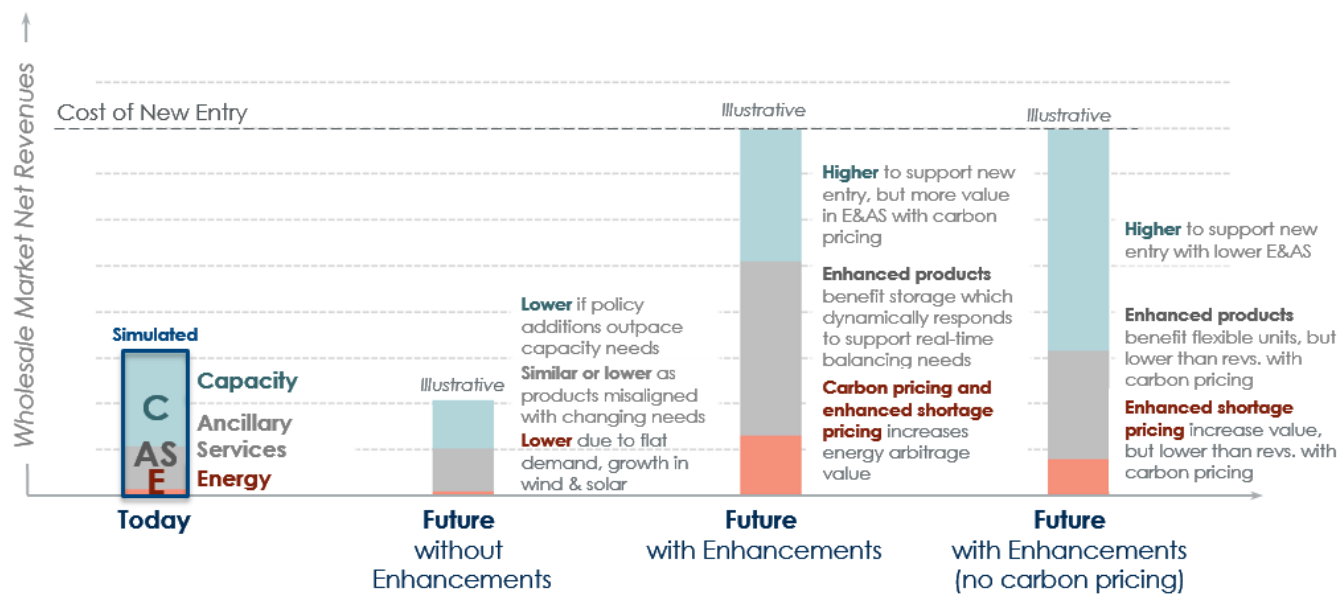


Figure 11: Illustrative Change in Revenues, Battery Storage (Assuming New Entry is Needed)



Enhancements to the Energy and Ancillary Services Markets

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 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 right type or quantity of resources to help balance such intermittent resources when they are not available. Finally, the energy market may under-engage the demand-side. It is expected that going forward market participation of demand will play a very important role in maintaining reliable operations and robust price formation.

Ongoing NYISO Efforts

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 (carbon) emissions associated with internal generation at a price per ton established by the New York Public Service Commission (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.[19] Costs to load-serving entities would not increase in the long run, however, largely because carbon charges would be disbursed back to customers.[20]

Carbon pricing would internalize the externality of carbon 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 RECs is entirely incompatible with wholesale markets. RECs pay for just the clean attribute that is unrelated to grid-services attributes reflected in the NYISO wholesale markets, but RECs 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

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19 See NYISO (2018c).

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

resources to site in locations/generate at times that displace the most carbon.

In addition, carbon pricing would incentivize competition from among low-cost sources of carbon 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 that are difficult to predict. More explicit carbon pricing would make REC procurements more effective by sharpening the rewards for clean energy produced at times and locations that reduce emissions the most, potentially achieving more carbon abatement from the same quantity of procured RECs. It could tilt any new investment in traditional generation toward the lowest-emitting technologies. It could also help support the upstate nuclear fleet—New York's largest sources of carbon-free generation—after the ZEC program expires, if nuclear plants are more economical than other clean resources.

Define Reliability Challenges

As discussed in this white paper, NYISO's changing resource mix will create new and different reliability challenges. Further analysis is paramount to better understanding these changes. Several challenges have already been identified by NYISO, including increasing supply variability and forecast uncertainty. These dynamics will likely require more flexible, fast-responding, standby capacity to fill in when wind and solar resources are unavailable. System inertia and interconnection frequency response is unlikely to be a concern in the short and medium term due to the large amounts of synchronized resources on the Eastern Interconnection, but may eventually become problematic.

NYISO has several ongoing efforts to evaluate reliability challenges, including the Enhancing Fuel and Energy Security project, the Reserves for Resource Flexibility project, and Large-Scale Solar on Dispatch project. Additional projects and analyses may be needed to holistically understand all challenges.

Enhanced Shortage Pricing

NYISO could enhance existing energy and shortage pricing in order to align prices with 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 from neighboring systems in a shortage event. 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

Evaluate Load Forecasting Approach

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 Load Forecasting Climate Change Impact and Resiliency Study is one ongoing effort to better understand these challenges.[21]

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 service 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[22], 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 for prioritization in the coming years.

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 five minutes for internal supply resources).

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[21] See NYISO (2019b).

[22] For more details on any of the projects in these sections, please see NYISO (2019a).

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. The NYISO has engaged the Analysis Group to conduct a study in 2019 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.

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.[23]

Efforts that Require Investigation and Careful Consideration

The recommendations in this section require study, further investigation, and discussion with stakeholders 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 required 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 do not need to run continuously. In this way

[23] See Analysis Group (2019) for the MIWG update.

demand can provide system control when there are more uncontrollable intermittent resources providing energy that are unable to provide these essential reliability services in real-time operation.

Multiple challenges exist prior to engaging the load participation. Most customers are not exposed to real-time prices; customers see flat prices or time of use rates that do not change with changing market 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 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 in real-time to set prices. Enabling loads to set prices is not a trivial change to NYISO market design and operations but in the future 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 market prices. The next step would be to integrate DER into the NYISO market design, which was recently approved by NYISO's Management Committee[24] 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 resource incentives for remaining flexible 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. The RTM is comprised 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

[24] See NYISO (2019d) for more information.

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 consider if there is a need for a third settlement either before the current DAM or between the DAM and RTC.

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 investigate 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 will continue 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 will require a robust set of market mechanisms, including both the E&AS markets and the capacity market.

The NYISO's energy and ancillary service 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 service markets alone do not provide enough revenue to attract sufficient investment to meet NYISO's traditional "1-day-in-10-years" resource adequacy standard[25]. 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.

The Capacity Product Definition Challenge

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 standard of less than one involuntary loss-of-load event every 10 years (or 0.1 loss-of-load event per year) in a system comprised of mostly dispatchable generators and reliability risks focused on a handful of peak load hours. It is an increasingly imperfect proxy in a future characterized by high levels of wind and solar generation. In such a system, 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 resources that are able to meet those needs. In this sense, the capacity product is one that starts to look like a physical reliability call option that can be called upon more than just a few peak hours, but at any time when the supply-demand balance approaches shortage conditions whether it is due to peak load or lack of generation due to intermittency of renewable resources. In this sense, the reliability call option that is today known as capacity may in the future depend more on commitments to load reductions and storage than has been the case in the past.

Without enhancements, a capacity construct focused primarily on having enough MW to meet forecasted peak demand (plus reserve margin[26]) may miss these increasingly diverse reliability challenges. Today's capacity product definition could therefore send the wrong signals to maintain the 0.1 loss-of-load event resource adequacy standard. The capacity product definition will need to evolve to reflect these emerging challenges.

The Resource Rating Challenge

Today's capacity market assigns capacity ratings to resources through different resource specific rules that generally reflect their expected level of availability during peak load hours. As reliability risks shift from peak hours to a more complex and diverse set of hours, resource ratings will need to evolve as well.

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25 The 1 day in 10 years resource adequacy standard refers to a reliability standard where no more than one involuntary regional loss of load is tolerated every ten years.

26 The reserve margin is determined by the Installed Capacity Requirement set by the New York State Reliability Council based on reliability considerations.

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 standard, even if some resources provide less value per nameplate MW than an always-available resource.

The NYISO calculates the Unforced Capacity (UCAP) of a unit using the historical availability of a generator and its Equivalent Forced Outage Rate-Demand (EFORd).[27]

For intermittent resources whose output is highly correlated with each other, the current ICAP approach of calculating average output over defined "performance hours" may not accurately reflect marginal reliability value. 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. Such conditions can result in the tightest supply conditions of the year when reliability is most threatened. Thus, the performance in these hours should be considered in any measures of marginal reliability value.

This problem of correlated performance affecting marginal reliability value 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 capacity ratings for duration-limited resources and is currently evaluating the resource ratings of intermittent wind/solar resources.

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27 See NYISO (2019e) section 4.5 for how to calculate UCAP for various other types of resources.

Ongoing NYISO Efforts

Enhancements to Resource Adequacy Models

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 Ratings to Reflect Marginal Reliability Value

The capacity value assigned to each capacity resource should reflect that resource's marginal contribution to reliability. 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 capacity 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.[28] 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, such as supply-assumptions. However, ELCC methods are increasingly utilized for determining solar and wind resource capacity values in other jurisdictions, including MISO, CAISO, and several utilities experiencing significant renewable resource additions (Portland General Electric and Xcel Energy 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.

[28] 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).

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 for prioritization in the coming years.

Capacity Demand Curve Adjustments

The capacity demand curve establishes the quantity of capacity NYISO purchased through the ICAP auction and the price NYISO paid for that supply. 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.

Comprehensive Mitigation Review

The Installed Capacity 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 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 funded primarily by privately owned capital, but new resource types such as battery storage, renewable generation and distributed energy resources (DER) are fundamentally different in design and operation. Additionally, these resources are more likely than traditional generator technologies to be partially funded by governmental entities to meet policy goals or promote environmental attributes. New rules and tests may be required to provide a better evaluation of these resources for instances of buyer-side market power and thus result in more accurate BSM determinations.

Efforts that Require Investigation and Careful Considered

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

Enhance Capacity Market Pricing

The one-day-in-ten-year resource adequacy standard can be met with various combinations of capacity in different areas of New York. The demand curve reset 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. Although the changes in the LCR implemented in 2018 are an improvement, the resulting capacity procurements and prices could be more efficient because they do not fully reflect the marginal reliability value of capacity. This raises the overall cost of satisfying the capacity needs. Reliance on four fixed capacity zones will 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 the 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 will include the 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 also reduce the costs 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).

Ensuring Year-round Resource Adequacy

NYISO requires the same quantity of ICAP capacity in both the winter and summer spot auctions, set based on summer peak. NYISO could consider procuring different amounts of capacity in each seasonal auction 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.

Protecting the Capacity Markets from Market Power

The two main mechanisms structured by the PSC to achieve the Governor's Clean Energy Standard Goals are the Renewable Energy Credits (REC) (intended for renewable resources such as wind and solar) and Zero Emission Credits (ZEC) (intended for upstate nuclear units, which contribute to carbon reduction in New York).[29] There is a legitimate concern that State subsidized renewable resources could have a

[29] See New York Department of Public Service (DPS) (2016) for a DPS Staff issued a whitepaper on January 25, 2016 outlining its recommendations to the NYPSC for implementing the state's Clean Energy Standard (CES).

> In support of these overarching objectives, DPS Staff recommended the formation of three tiers of resources eligible for support under the CES. Tier 1 is targeted at new renewable resources. Tier 2 targets existing renewable resources and is subdivided into merchant resources that are not under contract with the state or whose RPS contracts with the state expire (Tier 2A), as well as resources that are not eligible for RPS obligations in states with control areas adjacent to New York (Tier 2B). Eligible resources in Tiers 1 and 2 may be located in New York State or adjacent control areas provided they are able to deliver power into the New York Control Area. Tier 3 is designated for nuclear facilities in service prior to January 1, 2015 that are "facing financial difficulty as determined by a Staff examination of the books and records of the facility." Such facilities must be operating pursuant to a "fully renewed license by the NRC until 2029 or beyond" and eligibility for Tier 3 expires upon the expiration of any facility's current license term. In the case of Tier 3 nuclear facilities, DPS Staff recommends LSEs be obligated to

detrimental effect on electricity market price formation and threaten the viability of competitive non-subsidized resources. In this section, the NYISO articulates a framework for preserving competitive market resources while allowing State entities to pursue public policy goals within the context of competitive markets.

Market Compatibility of RECs

The current structure of providing REC-only contracts to competitively selected Large Scale Renewables (LSR) has a track record of compatibility with the competitive wholesale markets. RECs are procured competitively and compensate resources for attributes not valued in the wholesale market by providing payments for these attributes in an amount above wholesale market revenues. These additional payments allow renewable resources to compete with conventional resources. The exposure to market revenues necessitates renewable resources to be full participants in the wholesale markets and fully responsive to base points and other instructions from the ISO.

Other procurement options, such as long-term, bundled PPAs, Contracts for Differences (CFD) that operate as the financial equivalent of a long-term, bundled PPA (financially-equivalent CFDs), and utility-owned generation arrangements are problematic in terms of compatibility with the competitive wholesale markets to the extent that they insulate LSRs from wholesale market pricing signals. Any insulation from price signals has the potential to adversely impact the functioning of the wholesale markets and the reliability of the State's electric system as resources seek to maximize revenue opportunities without regard to system conditions. To date, the NYISO has worked effectively to ensure that LSRs are not fully insulated from wholesale price signals while operating an efficient, clean system that supports reliability.

Market Compatibility of ZECs

At the time of the NYDPS's Zero Emissions Credit (ZEC) proposal there were concerns within the NYISO's stakeholder community that actions to retain uneconomic resources were, and continued to be, an exercise of monopsony power by New York State entities, and should be subject to mitigation by NYISO. In an effort to reduce uncertainty and distinguish the NYDPS's ZEC proposal to retain the upstate nuclear units from other actions to retain units (with which it had publicly stated concerns), the NYISO filed comments on July 22, 2016 stating, "...based upon current market conditions, the DPS Staff's proposal does not raise wholesale market power concerns."[30].

procure Zero Emission Credits (ZECs) from eligible facilities rather than enter into bundled PPAs. Notably, the eligibility requirements for Tier 3 exclude Indian Point from potential participation regardless of its financial situation.

30 See NYISO (2016b), p 2.

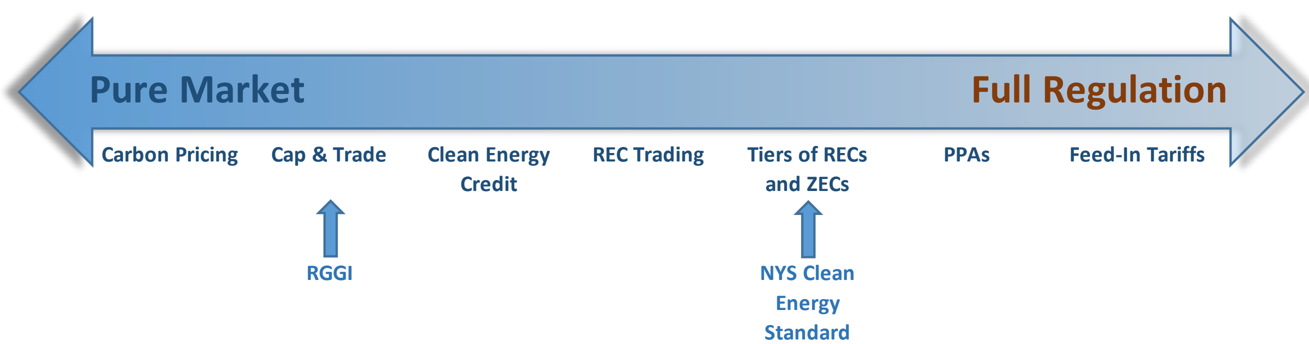
This statement was premised mainly upon NYISO's analysis of the cost effectiveness of the subsidy. In particular, NYISO analyzed the expected cost of a ZEC compared to the cost of other emission free resources subsidized by New York State. This analysis indicated that given the market levels at that time, and the subsidies for renewables via Renewable Energy Credits (RECs), the creation of ZECs appeared to be an economic decision. The cost of recent REC auctions was in the low $20 per MWh range, while ZECs were anticipated to be in the upper teens per MWh. It was therefore cheaper for the State to avoid carbon emissions by retaining the nuclear units via ZECs than to award incremental RECs. An economic decision such as this appeared to be consistent with competitive behavior, which generally does not warrant mitigation. The MMU concurred with the NYISO's analysis and conclusion.

An updated analysis of the ZEC program continues to show similar results and continues to support the NYISO's previous position that the program does not raise wholesale market power concerns. While there has been some convergence between ZEC and REC prices, ZECs remain the more economical option and carry a ~10% discount over the average price of RECs.

Market Compatibility of Carbon Pricing versus RECs and ZECs

The graphic below illustrates a range of policy options for New York to achieve the goals of the CES, attempting to arrange them according to their relative reliance on market versus regulatory forces to achieve those goals. The mechanisms currently chosen by the State, including RGGI, RECs and ZECs; while relatively market friendly are more closely tied to regulation. These mechanisms preserve operational response to market signals as well as dependence on market revenues for investment decisions. However, carbon pricing is superior to RGGI, RECs and ZECs in terms of integrating public policy into wholesale markets.

Figure 12: Spectrum of Policy Options



Harmonizing state goals and wholesale electricity markets is important for achieving State goals efficiently and maintaining the integrity of wholesale markets so they can continue to effectively meet reliability needs. An obvious way to harmonize wholesale electricity markets with de-carbonization goals is through carbon pricing.

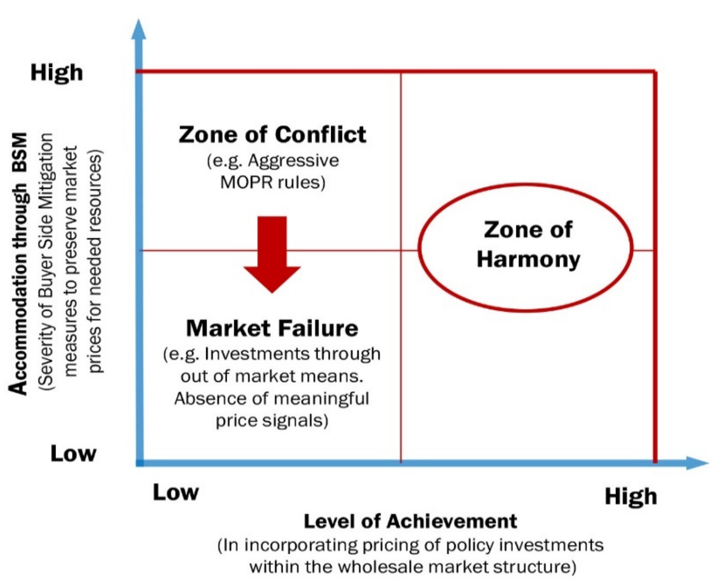
NYISO's Carbon Pricing proposal internalizes the cost of carbon emissions into the wholesale market energy prices, the levels of ZEC and REC payments are significantly reduced under a Carbon Pricing regime. In fact, according to the analyses performed by the Brattle Group, both ZEC and REC payments are sharply reduced by implementing Carbon Pricing with REC payments expected to be reduced by approximately the dollar-per-MWh equivalent of the carbon emission of the marginal unit. The current levels of carbon pricing being discussed. approximately $44 per ton on top of RGGI, are expected to produce roughly a $15 per MWh increase in energy prices resulting in an expected decline in REC values of $15 per MWh.

The potential elimination of the need for ZEC payments and significant reduction in REC payments under a carbon pricing regime, significantly reduces the pressure for structuring appropriate mitigation measures to preserve market prices at competitive levels. This would facilitate the retention of needed existing resources and facilitate the entry of needed new resources as well as the entry of needed new resources.

The context under which State Policy Goals and federally regulated competitive markets may play out

If Carbon Pricing is not implemented in New York, the figure below illustrates the level of "Accommodation" that may be needed depending on the manner in which state public policy objectives are achieved.

Figure 13: The level of "Accommodation" that may be needed



- **Symptoms of Conflict**
  - Conflict between State and Federal jurisdiction
  - Increased consumer costs
  - May lead to partial re-regulation or Market Failure
- **Symptoms of Market Failure**
  - Lack of meaningful price formation in wholesale markets
  - Investment decision made out of market
  - Managing intermittency increasingly difficult for system operator
  - Purpose of any remaining market functions is to optimize the operation of existing resources
- **Fruits of Harmony**
  - Investment signals largely from wholesale markets
  - Proper price formation incents desired real time response to balance intermittency
  - Market efficiency leads to lower consumer costs

Level of accommodation refers to the level of BSM measures applied to counteract the price suppressive effects of out-of-market investments. The level of achievement signifies the degree to which environmental attributes are directly incorporated into the markets. An example of a mechanism that will result in a high level of achievement is the incorporation of Carbon Pricing (incorporation of the social cost of carbon emissions in the market systems resulting in the LBMPs reflecting the cost of carbon).

Markets characterized by aggressive subsidization of public policy based resources and low level of accommodation for competitive resources creates a scenario where the markets only provide price signals for short run optimization of resources and most investment decisions are taken through out-of-market mechanisms. This is characterized by the "Zone of Market Failure" above.

An alternate scenario is a market with significant subsidies and aggressive use of buyer-side mitigation of Minimum Offer Pricing Requirements (MOPR) that are tailored to preserve market revenues for competitive resources. The diagram above characterizes this as the "Zone of Conflict" where aggressive countering of public policy initiatives through MOPR and other mechanisms cause conflicts with state regulators. The risk here is the resource adequacy function, which is preserved by the Capacity Market is taken over by state regulators who view the MOPR restrictions as unreasonable penalties. In this scenario, the state regulators mandate utilities to meet the resource adequacy requirements through long-term contracts. Over time, this would drive a region to write contracts that achieve public policies as well as retain uneconomic resources further pushing the competitive market for that region into the Zone of Market Failure

The Carbon Pricing proposal that NYISO is pursuing with the DPS staff involvement attempts to harmonize the NYISO-administered markets with the state's public policy initiatives. In this market-friendly scenario the market structure changes are targeted to incent real-time performance and provide adequate market revenues for non-subsidized resources needed for reliability. The NYISO's Master Plan outlines the areas for market enhancement tailored to a Carbon Pricing implementation.

Today, without Carbon Pricing within New York's wholesale markets, the State is relying on REC, ZEC and RGGI programs to achieve Public Policy goals. This is a less efficient mechanism for achieving policy goals and opens the door for further subsidies. It is to be noted that the State's REC and ZEC programs are market friendly and preserve incentives for public policy resources to respond to market signals. The State's REC and ZEC programs, in placing a price on emissions attributes, are far superior to feed-in tariffs, PPA and Utility Ownership of regulated resources that are prevalent in some PJM and ISO-NE states. Since RECs and ZECs can be market friendly, and the PSC and other state entities have a good track record of being responsive to NYISO's inputs to preserve market incentives, New York will still be in a better position to align its markets with the State's Public Policy initiatives. In the scenario of no Carbon Pricing, NYISO's Master Plan will need to be adapted to preserve market revenues for investment in competitive resources. The means by which this will be achieved are described in the section on Revenue Sufficiency with and without Carbon Pricing above.

A mitigation regime for NYISO under aggressive Public Policy Implementation

In the NYISO, BSM evaluations are performed on any incremental requests for capacity rights or new resources seeking capacity rights in the Lower Hudson Valley or NYC. BSM evaluates the economics of new entrants, and if these resources are not economic, they are given an offer floor for the capacity market. Currently, the only exemption from BSM (Competitive Entry Exemption) is for purely merchant facilities that have no impermissible contracts with prohibited entities. In addition, the NYISO has filed exemptions at FERC for renewable resources and resources meeting a load's own needs (self-supply). The renewable exemption is proposed to be capped at 1,000 MW a year. In addition to this filing, there are two other relevant complaints at FERC open on mitigation. The first is a complaint that the NYISO's existing BSM rules (for new entrants) should be extended to cover the entire NYISO market, and not just the Lower Hudson Valley zone and NYC. The NYISO has submitted analysis and testimony in this docket stating it does not support this rule change, as it is not necessary. The second complaint argues that existing resources that are "uneconomically" retained via subsidy should also be subject to BSM as well. This filing argued that resources that would likely exit the market, but are being compensated outside of NYISO markets via subsidy are suppressing the market prices, because without those subsidies, prices would increase.

The existing BSM rules were developed long before the State's Clean Energy Standard was envisioned. In the current context of aggressive implementation of the State's Clean Energy goals, the NYISO's mitigation rules, particularly the administration of BSM needs to be examined in a comprehensive manner to allow the wholesale markets function efficiently while contributing to the achievement of the State's Public Policy goals. Formulation of a practical but effective framework for administration of market mitigation measures is integral to the plan to address reliability and market considerations for a grid in transition.

The NYISO plans to engage with stakeholders to formulate a comprehensive review of the BSM structure aimed at preserving market pricing levels that would allow for retention of existing market-based resources as well as entry of new market-based resources to meet reliability needs. The NYISO expect that this effort would commence in 2020.[31]

[31] See NYISO (2019a).

While that study will inform potential market designs, the NYISO currently anticipates engaging with stakeholders on two parallel but complementary paths. The first approach, which is similar to the ISO-NE CASPR (Competitive Auctions with Sponsored Resources) mechanism, investigating the suitability of an orderly retirement of excess conventional resources by pairing these retirements with the entry of Public Policy based renewable resources. The second approach recognizes non-market revenues associated with environmental attributes as part of the BSM Part B evaluations.

Possible enhancements to BSM Evaluations

Testing for BSM consists of two parts – Part A Test and Part B test. Recognizing that electricity markets do not fully incorporate environmental attributes which are very important to State Regulators and the Public, the NYISO is considering formalizing the BSM rules to recognize the value of external environmental attributes in the BSM evaluations.

RECs and the Part A BSM Test

The purpose of the Part A test is to ensure that a resource will be determined to be exempt when its capacity will be needed to satisfy the capacity requirement for a particular Locality. This exempts resources when the surplus capacity margin in a local capacity zone drops below 6 percent in Zone J or 5 percent for the G-J Locality.

The amount of surplus capacity needed is determined by the Installed Capacity Requirement set by the New York State Reliability Council based on reliability considerations. It should be noted that every megawatt of new public policy based renewable resource does not lead to a corresponding megawatt of increase in surplus capacity as the process for setting the Installed Capacity Requirement recognizes the intermittent nature of renewable resources and adjusts the requirement upwards to preserve reliability. In the July 2016 filing to the PSC, the NYISO noted that the level of renewables needed to meet the State's 2030 Goals would entail an increase of the Installed Capacity Requirement from 17.5% to 40-45%. The net effect of this is that the surplus does not increase at the same rate as renewable addition and new renewable resources may pass the Part A test. This is illustrated in Table 4 below where the addition of 15,000 MW of public policy renewable resources increases the level of surplus by approximately 6000 MW. This implies that 6000 MW of existing capacity would have to retire before price levels recover to levels that prevailed prior to the introduction of public policy renewable resources. Absent these retirements, public policy renewable resources would likely not pass the Part A BSM test. However, the MMU has encouraged the NYISO to explore an ISO-NE CASPR-Like Mechanism to allow resources to enter the market paired with the retirement of existing conventional resources. This will allow an orderly retirement of less competitive conventional resources and contribute to maintaining competitive market price levels for all resources.

Table 4: The effect of the addition of 15,000 MW of public policy renewable resources

	Peak Load (MW)	Existing Capacity (MW)	New Renewables (MW)	Installed Capacity (MW)	IRM %	ICAP Requirement (MW)	Excess (MW)	Increased Surplus (MW)
Case I	33,000	40,000	-	40,000	17.5	38,775	1,225	-
Case II	33,000	40,000	15,000	55,000	45.0	47,850	7,150	5,925

In New England, the ISO-NE Competitive Auctions with Sponsored Resources (CASPR)[32] accommodates public policy resources into the Forward Capacity Market (FCM) over time, while minimizing the impact that such resources have on competitively based capacity prices that encourage the development of resources in the region when needed. CASPR introduces a Substitution Auction (SA) that runs immediately after the Forward Capacity Auction (FCA) to coordinate the entry of new publicly sponsored resources in the capacity market with the exit of older existing capacity resources willing to permanently leave. The SA settles at a distinct clearing price, based on its supply and demand, which is paid by the retiring resources to the new public policy resources that take on the Capacity Supply Obligations of the FCM. Existing resources that exit the market via the SA receive a final payment equal to the difference between the (higher) FCA clearing price and the (lower) SA clearing price. By pairing entry and exit in the SA, over-supply concerns are reduced and resource adequacy in New England is maintained.

In New York where there is no Forward Capacity Market, a CASPR-like mechanism may be constructed by allowing Public Policy resources to buy Capacity Resource Interconnection Service (CRIS) from an existing resource with the obligation for the existing resource to retire before the CRIS rights are transferred and receive an exemption from BSM. This could be set up as a simple bilateral transaction, which is recognized and administered by the NYISO. This new mechanism may be viewed as an enhancement to the existing Part A BSM construct.

RECs and the Part B BSM Test

The purpose of the Part B test is to ensure that a resource is not subject to an offer floor under BSM if that resource is economic. REC auctions have been prevalent in New York for over a decade and have led to competitive market outcomes that supports considering them as market revenues for desirable environmental attributes. In the past, the NYISO has recognized the value received in the REC auction as market revenues. The contemplated initiative would explore with NYISO Stakeholders and the MMU

32 Independent System Operator of New England (ISO-NE) (2019).

whether the NYISO should recognize such revenues more broady in BSM evaluations given the context of increasing levels of public policy based intermittent resources.

If new REC-like mechanisms are structured by the New York State for off-shore wind renewable energy credits (ORECs), the consideration of the outcome of these auctions in terms of recognition in BSM evaluations will also need to be discussed with stakeholders and the Market Monitoring Unit (MMU).

Current Stakeholder Initiatives on BSM Enhancements

In addition to the enhancements to the evaluations envisioned above, there are a number of current initiatives in discussion with stakeholders. These include Competitive Entry Exemption (CEE) for increased CRIS and Modifications to Facilitate Repowering. In the Increased CRIS initiative, increases in capacity obtained through competitive means would be considered exempt from BSM. The NYISO is looking at modifications to the CEE rules which would allow for resources with non-discriminatory, short term procurement contracts to qualify for this exemption. It is expected that this may ease some of the obstacles to repower facilities in the Mitigated Capacity zones.

Further, the NYISO anticipates that – as part of revisions to its interconnection process that it is currently considering– it will look for opportunities to expedite review time for certain small resources under the BSM rules.

Planned Market Design Changes

The NYISO will work 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. As described above in the section titled *Revenues for 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

The NYISO wholesale markets have 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 owners of new generation, to replace more than 7,000 MW of retirements. The entire time, the markets have maintained high operational reliability with limited out-of-market interventions. According to the external MMU, the NYISO's market outcomes have consistently been competitive. The

MMU further observes that the markets 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.

Now, New York's electricity industry is transforming rapidly, from traditional, controllable fossil generation to non-emitting, weather-dependent intermittent and distributed generation with near-zero variable cost. While state policies play a key role, technological advancements are expanding the possibilities of new resources and lowering their costs. New York State programs aim to serve 50% of load with renewable energy by 2030. The Governor's proposed Green New Deal would further mandate 100% clean power by 2040, increase the Clean Energy Standard mandate from 50% to 70% renewable energy by 2030, and provide a number of additional renewable energy mandates.

In aggregate, these policies strains the NYISO's ability to deliver reliable supply at competitive costs with the current market rules. Any enhancements to the market must take into account the myriad of policy drivers and their impacts on the wholesale market. This poses reliability and economic challenges that NYISO must address.

The NYISO is actively studying these questions to develop a plan to successfully meet these future challenges. We approach these questions with two guiding principles: (1) maintain all aspects of grid reliability; and (2) competitive markets should continue to guide investment and facilitate grid operations, in order to maximize economic efficiency and minimize the cost of maintaining reliability. The key is to anticipate the needs for existing and new grid reliability services and proactively evolve the wholesale market design to meet those needs. Wholesale markets must continue to reflect all needs through product definitions that support grid reliability services. Product pricing must reflect the marginal cost to serve or forego (when supply is scarce) the reliability need. **Prices can thereby serve as a powerful control signal: they rise where and when necessary to attract and elicit essential grid services.**

Therefore, 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 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 capacity market enhancements because real-time prices can reflect varied and dynamic operational needs better than any products that might be procured as "capacity."

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 15-30 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.[33] 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.[34] Wind and solar are rarely marginal (less than 5% of intervals from 2015 – 2017), and have not yet had a significant effect on prices.[35] 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

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

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

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

ancillary 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; [36] 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.[37] 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.[38] 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.[39] These are illustrated in Figure 14.

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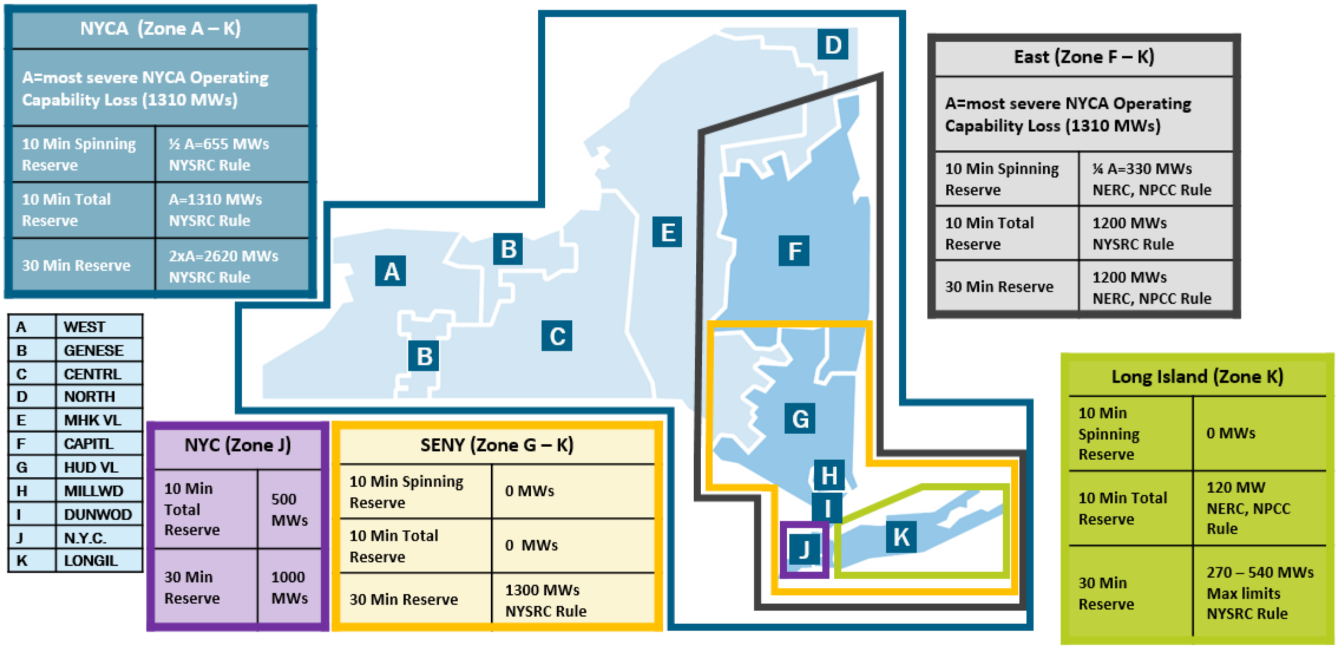
36 See Potomac Economics (2018), p. A-16.

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

38 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.

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

Figure 14: NYCA Operating Reserves with proposed Zone J Operating Reserves



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)[40]
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* Supply resources already synchronized to the system that can respond to instructions from the NYISO to change output level within 30 minutes. *30-Minute Non-Synchronized Reserves* Supply resources that can be started, synchronized, and loaded within 30 minutes.	Online generators 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.[41] Prices fell from 2016 to 2017 despite an increase in energy prices in most areas due to lower offer prices.[42] 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 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

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

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

42 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.

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 service revenue to ensure resource adequacy to meet mandated reliability standards.[43] 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

[43] 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).

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.[44] 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 installed capacity 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.[45]

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
- 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

44 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.

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

- 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 Interconnection) 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: Revenue Analysis Details

This appendix provides the assumptions used in the revenue analysis described in the Revenue Sufficiency With and Without Carbon Pricing section.

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 service 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 battery 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)
- Battery 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 6 through Table 8 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 (2019).

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-min non-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 9 below.

Table 9: Key Market Assumptions and Data Sources

Market Parameter	Assumption	Source
Price of Natural Gas	Zones C & G: Transco Z6 NY 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) $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 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 & 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 service revenues. For the existing Zone J steamer, average going forward costs from the Potomac Economics (2018) are shown in the row labeled "Gross CONE".

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