Fuel and Energy Security In New York State

An Assessment of Winter Operational Risks for a Power System in Transition

FINAL REPORT

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Acknowledgments

This report has been prepared at the request of the New York Independent System Operator (NYISO), to conduct a forward-looking assessment of the fuel and energy security of the New York electric grid during winter operations.

This is an independent report by Paul J. Hibbard and Charles Wu of Analysis Group, Inc. (Analysis Group, or AG), and reflects the judgment of the authors alone. They wish to express their sincere appreciation for the assistance of colleagues at Analysis Group: Grace Howland, Hannah Krovetz, Benjamin Dalzell, and Jacob Silver (Mr. Dalzell and Mr. Silver recently left Analysis Group to pursue graduate professional studies). Also, our work has benefitted from input and comment from the NYISO and its market participants and stakeholders.

About the Authors

Paul Hibbard, a Principal in Analysis Group's Boston office, has public and private sector experience in energy and environmental technologies, economics, market structures, and policy. Mr. Hibbard's work has addressed the implications of new public policy programs; the impacts of infrastructure development options on market pricing and ratepayer costs; the evolution of electricity market structures and wholesale rate design; utility ratemaking practices; and the transfer of U.S. federal and state emission control programs to other countries. He served as chairman of the Massachusetts Department of Public Utilities, was a member of the Massachusetts Energy Facilities Siting Board, and has testified before Congress, state legislatures, and federal and state regulatory agencies. Mr. Hibbard also has authored numerous articles, white papers, and reports for journals, foundations, commissions, and industry organizations.

Charles Wu, an Associate in Analysis Group's Boston office, has extensive experience in the assessment and design of wholesale electricity markets in Northeastern U.S. power market regions. Mr. Wu's work has included review and analysis of generating unit performance in and design parameters affecting capacity and energy markets in New England and New York; the development of power market models to evaluate unit performance and profitability; and the assessment of changing infrastructure and public policy on economic, consumer and environmental impacts through economic and production cost modeling. Mr. Wu has experience consulting on energy economics, securities, trade disputes, mergers and acquisitions, and financial disputes.

About Analysis Group

Analysis Group is one of the largest international economic consulting firms, with more than 1,000 professionals across 14 offices in North America, Europe, and Asia. Since 1981, Analysis Group has provided expertise in economics, finance, health care analytics, and strategy to top law firms, Fortune Global 500 companies, government agencies, and other clients worldwide.

Analysis Group's energy and environment practice area is distinguished by expertise in economics, finance, market modeling and analysis, regulatory issues, and public policy, as well as deep experience in environmental economics and energy infrastructure development. Analysis Group has worked for a wide variety of clients including (among others) energy producers, suppliers and consumers, utilities, regulatory commissions and other federal and state agencies, tribal governments, power-system operators, foundations, financial institutions, and start-up companies.

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I. Executive Summary

A. Background and Study Context

The NYISO is responsible for the reliable planning and operation of the state's bulk power system and the design and administration of the state's competitive wholesale markets. Over twenty years of operations, the NYISO has maintained system reliability and improved its competitive market designs, while addressing - from both planning and operational perspectives - continuous changes in the infrastructure, fuels, and policies that drive evolution of the power grid. Two key factors have dominated this evolution in recent years, a trend that is likely to accelerate in years to come. The first is the emergence of low cost natural gas - with the arrival of shale gas - as the fuel of choice for new generating infrastructure development; the second is energy, environmental and climate-related policies that seek to achieve the decarbonization of the state's economy against a backdrop of declining costs of certain renewable resource options.

These changes have significantly altered and affected the resource fleet in New York, and have driven a greater dependence on natural gas and renewable resources for power system operations.[1] As seen in Figure ES-1 and Figure ES-2, since 2000, over 7,000 MW of existing generation resources have retired or suspended operation in New York, including nearly all coal-fired capacity, while over 11,000 MW of capacity from new generating units and unit upgrades have been added - largely gas fired or dual-fuel units with gas as their primary fuel, and renewable resources (wind and solar).[2] In terms of annual generating capability, since 2000, the production capability of units with natural gas as the primary fuel has increased from 47 percent to roughly 60 percent.[3]

Over this period the increased reliance on natural gas in New York has contributed to meaningful benefits, as both the price of electricity and the emissions associated with power system operations have declined.[4] These benefits have been largely driven by the displacement of older, less efficient and more polluting fossil fueled generation with newer, more efficient and less polluting natural gas-fired generation, as well as renewables.

The increasing reliance on natural gas and weather-dependent renewables - and continued dependence on oil-fired generation during winter months - do not *necessarily* increase the challenges associated with reliable system operations, and do not by definition increase the risks associated with maintaining system reliability. Nevertheless, in light of the current circumstances and context, NYISO asked Analysis Group to undertake a reliability assessment focused on fuel and energy security risks during winter operating conditions.

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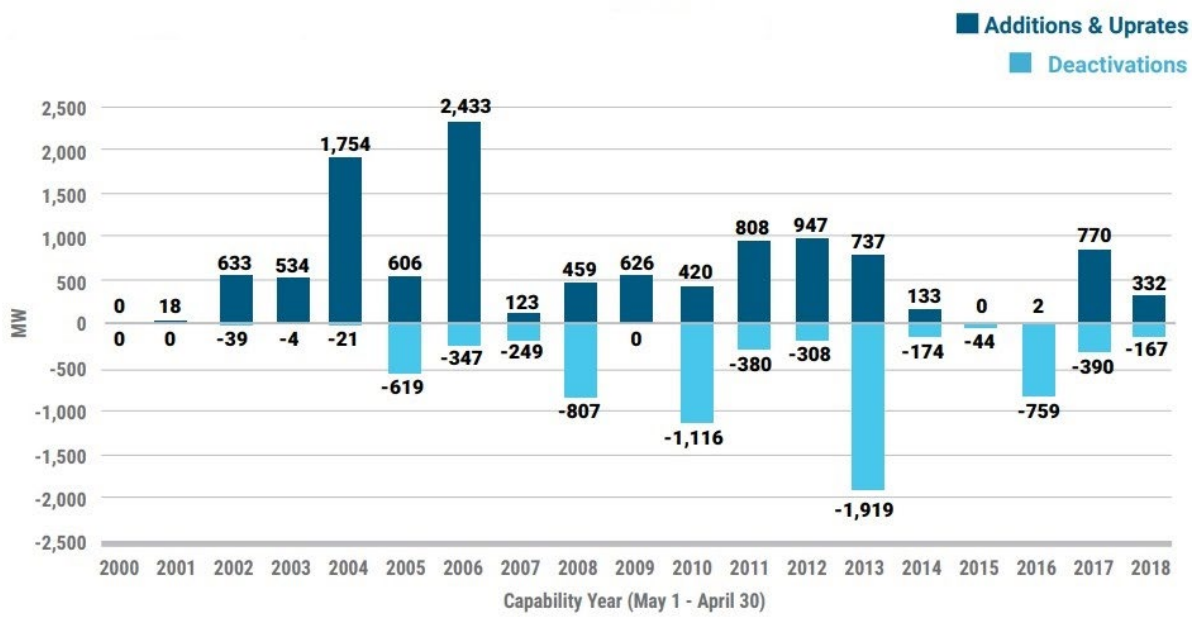
[1] New York Independent System Operator, "Reliability and a Greener Grid, Power Trends 2019," pages. 17-18 (hereafter "NYISO Power Trends 2019"), available at https://www.nyiso.com/documents/20142/2223020/2019-Power-Trends-Report.pdf/0e8d65ee-820c-a718-452c-6c59b2d4818b?t=1556800999122.

[2] NYISO Power Trends 2019, pages. 17-18.

[3] NYISO Power Trends 2019, page. 30.

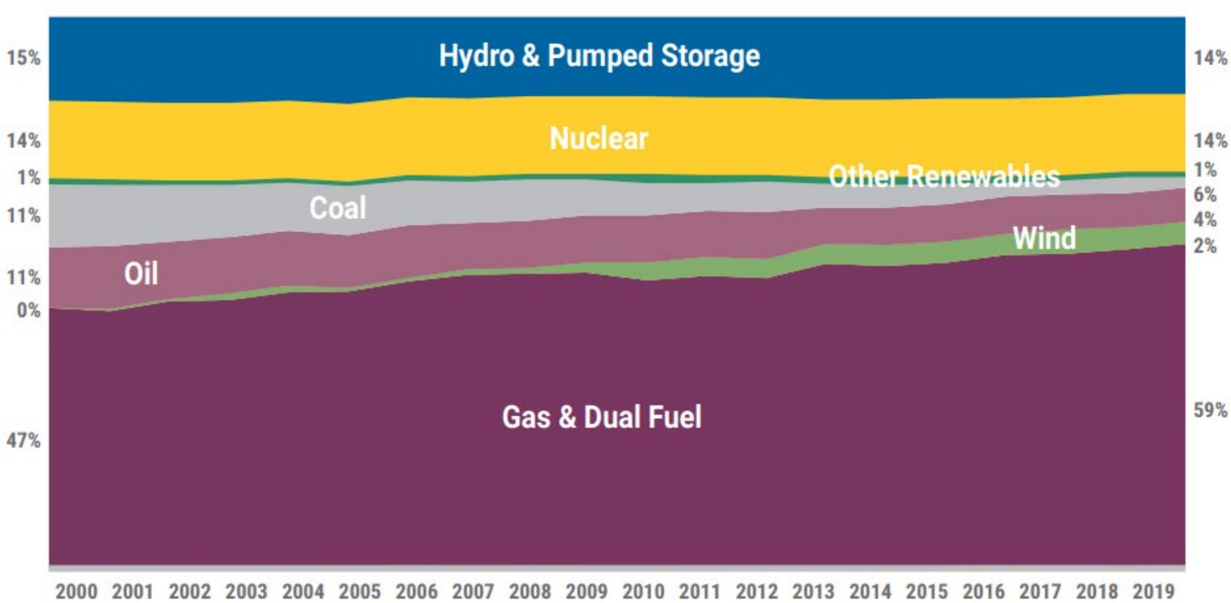
[4] NYISO Power Trends 2019, page. 33.

Figure ES-1: Additions, Uprates and Deactivations (Nameplate Capacity)



Source: NYISO Power Trends 2019, page. 18.

Figure ES-2: New York State Fuel Mix Trends: Capacity 2000-2019



Source: NYISO Power Trends 2019, page. 30.

Several factors suggest that continued monitoring and analysis of the ongoing transition of the resource fleet on the reliable operation of the NYISO power grid are warranted.

1. First, in general, increased dependence on any one fuel has the potential to decrease the diversity of power system infrastructure, and reduce the reliability benefits that flow from greater diversity (in the fuel source, location, size, and operational modes of power system generating resources).
2. Second, in particular, the growth in reliance on natural gas and renewables has coincided with the retirement of generating capacity operating on other fuels (typically stored on-site), and the potential - or likely - continued retirement of oil, coal, and/or nuclear capacity, reducing overall system-wide fuel diversity.
3. Third, the state's continued efforts to reduce emissions of harmful pollutants and decarbonize all sectors of the economy - most recently through enactment of the Climate Leadership and Community Protection Act (CLCPA)[5] - have potentially two significant outcomes: 1) a continued decline in oil-fired and other fossil-fired generation capacity that is currently critical for reliable winter system operations downstate, and 2) a potentially major increase in (and change in the shape of) demand for electricity, due to electrification of the building, transportation, and other sectors of the economy. This electrification is likely needed to meet the CLCPA's economy-wide greenhouse gas (GHG) reduction requirements.[6]
4. Finally, despite the need to reduce fossil fuel combustion in total across all sectors to meet the state's GHG emission reduction targets, fossil-fired generation (including natural gas) will be needed for reliable power system operations throughout this transition, to support electrification of other sectors, and help manage the greater variability of increasing quantities of weather-dependent renewable generating resources. It is difficult to forecast what the role for gas-fired generation is over the next couple decades, yet it seems likely to take on greater importance for power system reliability in the near to intermediate term.

The state of New York has witnessed significant changes over the last decade and a half, driven primarily by public policies and the emergence of natural gas as the fuel of choice for electricity generation. Going forward, the state is embarking on an ambitious and challenging period of transition - one that may require an unprecedented level and pace of change in power system infrastructure and operations to achieve the GHG reductions in all sectors of the economy required by the CLCPA. In this context, it is a good time for NYISO, electricity market participants, and stakeholders to consider the current risks - if any - associated with winter system operations, and to explore the key factors that will likely drive how these risks may change over time.

B. Study Purpose and Method

1. Purpose

The mix of fuels used to generate electricity affects both the reliability and resilience of the bulk electric system. A balanced array of resources enables the system to better address issues such as price volatility, fuel availability and stressed/abnormal operating conditions. New York's electric generation fleet has historically been comprised of a relatively diverse mix of fuel types.

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[5] Chapter 106 of the Law of the State of New York of 2019.

[6] Some of the standards established by the CLCPA include: (1) a goal to reduce GHG emissions 85% over 1990 levels by 2050, with an incremental target of at least a 40% reduction by 2030; (2) producing 70% of electricity from renewable resources by 2030 and 100% from zero-carbon resources by 2040; (3) increasing energy efficiency by 23% over 2012 levels; (4) building 6 GW of distributed solar by 2025, 3 GW of energy storage by 2035, and 9 GW of offshore wind by 2035; (5) electrification of the transportation sector, as well as water and space heating in buildings.

The confluence of technological advancements, environmental and economic considerations, and public policies are driving significant changes to the portfolio of supply resources in New York. These conditions highlight the potential for future challenges to arise in meeting electric system demands under certain stressed conditions such as prolonged cold weather events and/or fuel supply or transportation availability constraints or disruptions.

In response, the NYISO engaged Analysis Group to assist in conducting a forward-looking assessment to examine the fuel and energy security of the New York electric grid. Analysis Group was tasked with assessing winter fuel and energy security risks and identifying key factors that will affect the likelihood and potential severity of any risks.

The analysis was not designed to focus on the questions of economics or consumer costs, and does not involve use of production cost modeling. Instead, the assessment is a deterministic, scenario-based winter reliability assessment.[7] It represents an evaluation of potential reliability risks and impacts under *severe* winter conditions and *adverse* circumstances regarding system resources, physical disruptions, and fuel availability. The objective is to better understand under what combinations of severe winter weather and highly adverse system conditions the reliability of the power system might be vulnerable, and what the potential impacts could be under such conditions.

2. Fuel and Energy Security Model

Analysis Group developed and applied its fuel and energy security model to comprehensively assess the risks of wintertime operation under adverse conditions, with specific application to the NYISO power system. The starting point for the analysis is expected system conditions for a future winter season - the winter of 2023/2024. System demand, supply resources, and transfer capabilities are based on previously-vetted NYISO study assumptions, including the most recently completed the Congestion Assessment and Resource Integration Study (CARIS) Phase 1 analysis.[8] The extended period of cold weather used in the assessment was based on analysis of 25 years of historical weather data. The cold weather period used spans seventeen consecutive days of frigid winter conditions, including a historic three-day severe cold weather event (occurring on days six through eight of the event).[9] The energy and fuel security analysis included the following data and modeling steps, conducted where appropriate for specific locations (zones or combination of zones) within New York (see Figure 13):[10]

1. Weather: Identify severe winter conditions based on historical winter weather data, and use this to identify an appropriate extended "severe cold weather event" in terms of length, daily heating degree days, and including a short period of very severe weather within the duration of the extended event.
2. Electric and Gas Demand: Using historical data, establish locational relationships between temperature (heating degree days) and two factors affecting natural gas use and availability: (a) local gas distribution company (LDC) retail gas demand and (b) electric load.

[7] The deterministic analysis stack-orders the operation of generating unit and fuel types based on fuel availability and relative efficiencies, and compares available output to demand for each case analyzed. The model is described in full in Section III.

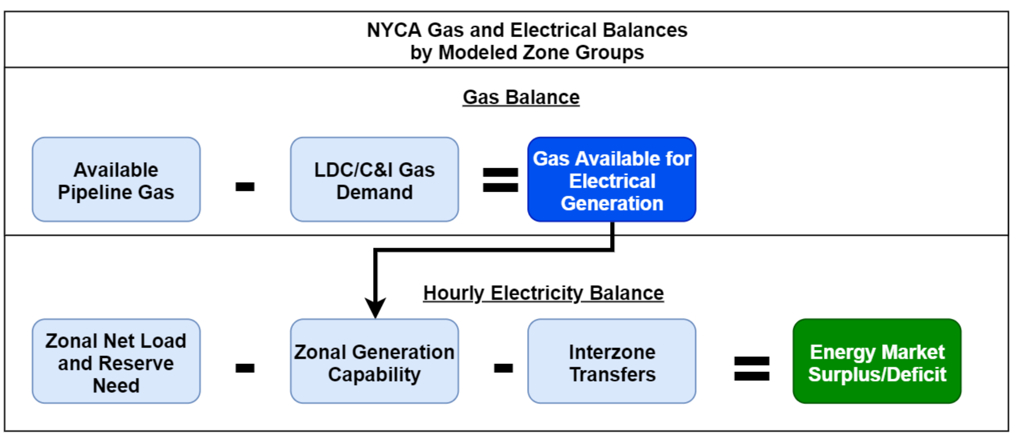
[8] New York Independent System Operator, "2017 CARIS Phase 1 Report: Congestion Assessment and Resource Integration Studies," April 2018 (hereafter "2017 CARIS Report"), available at https://www.nyiso.com/documents/20142/1402648/05_CARIS2017_Report.pdf.

[9] In effect, the modeled severe cold weather event represents a worst case string of temperatures over a fourteen day period and three-day cold snap, based on data over the past two and a half decades.

[10] Each component of the fuel security model and analysis, and the data and assumptions applied, are described in more detail in Section III and the Appendices.

3. Fuel: Using historical data reported by generation resources to the NYISO, (1) evaluate the likely inventories and refill capabilities for oil-fired (including dual fuel) units, and (2) establish locational relationships between temperature (heating degree days) and two factors affecting natural gas use and availability: (a) LDC demand and (b) electric load during the winter.
4. Pipeline Capacity: Using public data from the U.S. Energy Information Administration (EIA), interstate pipelines, and other sources, estimate the capacity of natural gas infrastructure in New York to deliver natural gas for meeting both LDC retail gas demands and power system needs, net of what is known to be committed to export to surrounding states/regions.
5. Natural Gas System Balance: Use items #2 and #4 above to determine a *natural gas system balance*, approximating the availability of non-firm natural gas for power generation on a daily basis over the extended severe cold weather period modeled;
6. Power System Resources: Combining estimates from item #5 and data on non-gas resource availability, identify the resources expected to be available for electricity generation under the modeled winter conditions, and stack order them based on likely output, availability of fuel, and operational efficiency, to determine total potential generation and transfers between locations in New York on an hourly basis over the modeled cold weather period;
7. NYISO Actions: Identify hours where NYISO actions to reduce energy-only exports to New England or activate wholesale demand response resources (specifically, Special Case Resources [SCRs] and/or the Emergency Demand Response Program [EDRP]) are necessary to meet load or maintain reserves, and model the effect of such actions; and
8. Electric System Balance: Compare the hourly zonal demand for energy with the available electric generation (and inter-zonal transfer capability) to identify the *electrical supply/demand balance* on an hourly basis.

Figure ES-3: Gas and Electrical Balance Model



Using the aforementioned assumptions and model logic, the analysis evaluated a wide range of cases that vary along two dimensions: "scenarios" represent potential variations in the configuration of resources, fuel availability and power transfers in the future year, and "physical disruptions" (evaluated singularly or in combination) primarily identify episodic conditions that do not necessarily reflect permanent system changes.[11] In total, the analysis assessed system performance across nearly one hundred "cases," each representing some combination of the identified scenarios and physical disruptions.[12]

The primary scenarios assessed are summarized in Table ES-1, with each scenario representing different combinations of (a) timeframe for the development of new renewable resources; (b) capacity imports from neighboring regions; (c) potential retirement of units affected by the New York State Department of Environmental Conservation (NYSDEC) proposed NO_x emissions requirements for simple cycle and regenerative combustion turbines ("peaker rule"); and (d) availability of natural gas for power generation.

Each scenario described above was also run against 11 physical disruptions, which involve various events or contingencies with respect to unit performance/availability, oil inventories, oil refill rates, and disruptions of natural gas delivery. The physical disruptions are summarized in Table ES-2.[13]

Table ES-1: System Scenarios

Scenario Type	Infrastructure	Imports	Oil	Natural Gas
Description	**REN:** delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of 2017 CARIS Phase 1 "System Resource Shift" case assumed levels	**IM900:** 900 MW capacity imports **IM0:** 0 MW capacity imports	**PK:** potential retirements in response to the requirements for 2023 set forth in the proposed "peaker rule"	**NGR:** Reduced non-firm gas availability to support ~2000 MW of gas-fired generation in zones A-F, ~1000 MW of gas-fired generation in zones G-I, and no non-firm gas to support generation in zones J and K
Scenario 1		**IM900**		
Scenario 2		**IM900**	**PK**	
Scenario 3		**IM0**		
Scenario 4		**IM0**	**PK**	
Scenario 5		**IM900**	**PK**	**NGR**
Scenario 6	**REN**	**IM0**	**PK**	
Scenario 7		**IM0**	**PK**	**NGR**
Scenario 8	**REN**	**IM0**	**PK**	**NGR**

[11] A number of additional cases were also run to test the impact of issues identified by Analysis Group or raised in NYISO and stakeholder discussions. For example, the potential impact of adding offshore wind, connected into downstate New York was also assessed. Where relevant, the results of these additional cases are discussed below and in the Sections that follow.

[12] The cases reviewed are described in more detail in Section IV, and full case results are presented in detail in Appendix E.

[13] Scenarios and physical disruptions are described in more detail in Section V.

Table ES-2: Physical Disruptions

#	Disruption Name	Description
1	**Starting Conditions**	No physical disruptions
2	**SENY Deactivation**	Loss of significant capability (1,000 MW) in SENY (specifically, zones G-I)
3	**High Outage**	Double unit forced outage rate compared to historical averages
4	**Nuclear Outage**	Loss of major nuclear facility upstate
5	**No Truck Oil Refill**	Unavailability of truck oil fuel delivery based on historical events such as snow storms
6	**No Barge Oil Refill**	Unavailability of barge oil fuel delivery based on historical events such as rivers freezing
7	**No Oil Refill**	Unavailability of any oil fuel delivery due to severe fuel limitations affecting both barge and truck refueling
8	**Non-Firm Gas Unavailable F-K**	No gas-fired generation capability available in zones F-K
9	**Low Fuel Inventory**	Reduction of initial oil storage by unit and oil fill max tank quantity to half of historical averages
10	**Non-Firm Gas Unavailable NYCA**	No gas-fired generation capability available anywhere in the New York Control Area (NYCA)
11	**Extreme Disruption**	Combination of no gas-fired generation capability available anywhere in NYCA, loss of significant dual fuel capability in zones G-I, and unavailability of any oil refill capability

3. Evaluation Method and Metrics

A goal of the analysis was to identify any cases where there was a potential loss of load (LOL) event in any zone, or where conditions triggered leading indicators of potential reliability challenges - that is, where conditions were tight enough to require operational steps to preserve system reliability (such as a reduction in energy-only exports, activating SCRs/EDRP, or a shortage of required reserves). Outputs of the various case runs were created to capture these conditions, and quantify them in terms of (a) magnitude of a potential load deficiency (in megawatts (MW)), (b) duration of deficiency (in hours or days), and (c) frequency of the occurrence of deficiencies over the course of the modeled cold weather period.[14] Results for each case were synthesized in tabular and graphical

[14] In addition to a complete representation of events or cases where there was a potential loss of load event, the metrics also quantify occurrences where the leading indicators are triggered (reduction in energy-only exports, activation of SCRs/EDRP, and/or violation of reserve requirements).

forms to provide a comprehensive representation of the nature and magnitude of the fuel/energy security reliability risks (if any) under the range of system scenarios and physical disruptions analyzed.[15]

An additional step of the review involved an evaluation of the likelihood of case outcomes.[16] This evaluation of likelihood was intended, in combination with the model's consequence analysis, to focus the review on a subset of cases that are both consequential and whose likelihood is at least on a par with system conditions and events that might typically be considered in system operational analyses. The final step of the analysis involved careful review of case outcomes, with a particular focus on cases that - based on the reliability impacts of the case and the likelihood of realization - involved (a) potential conditions or system circumstances that could or should be evaluated in more detail, or (b) potential risks that warrant consideration of mitigating action.

C. Key Findings and Observations

1. The Changing Context for Fuel and Energy Security in New York State

With continued operation and availability of most of the assets expected to be in place in the winter of 2023/2024, the New York power grid is currently well equipped to maintain reliability in the winter, even under adverse winter system conditions. Only fairly severe and relatively low probability conditions or events would create meaningful reliability challenges to the state.

Below is a summary of the assessment and key findings from the analysis based on existing resource expectations and conditions likely reflective of winter 2023/2024. However, where relevant, findings related to the state's longer-term expectations are also highlighted. In the context of fuel and energy security, the biggest challenge for New York State, NYISO, and stakeholders over time will likely be in navigating the state's power system transition towards decarbonization in a way that does not jeopardize or compromise the resources, performance capability and infrastructure needed to support reliable winter operations.

The transition of the power grid - as evidenced by the requirements set forth in the CLCPA and other policies established by the state legislature and regulatory agencies in recent years - involves rapidly declining reliance on fossil fuels, and increasing reliance on weather-dependent renewables, energy storage, and other low-/no-carbon resources. Demand for electricity may substantially increase (and potentially change significantly in shape) over the next two decades, assuming electrification represents an efficient and least-cost path to decarbonization of transportation, building, and other sectors of New York's economy. Yet at the same time, the CLCPA requires that 70 percent of the state's electricity be provided by renewable generation by 2030, and 100 percent of the state's electricity be provided by zero-carbon generation by 2040.

The ongoing transition of the power system is an important consideration, particularly in light of the findings in this report (summarized below). This review is focused on a "snapshot" of future system conditions in the winter of 2023/2024; yet at that time, changes in response to the CLCPA with the introduction of new resources and the changing economics of existing resources will only be just beginning to take hold. Putting the analysis into the context of the continued evolution of the power system beyond winter 2023/2024, one thing stands out: the availability and consistent contributions of adequate amounts of natural gas-fired and oil-fired (or dual fuel) generating resources is necessary to maintain power system reliability in cold winter conditions. This is particularly true for Long Island and New York City. Simply put, avoidance of potential loss of load events in these load

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[15] A complete description of model output metrics and illustrative tables and charts is presented in Section V.

[16] A full description of our evaluation is presented in Sections V and VI.

centers, under plausible adverse winter conditions, requires operation of natural gas and oil-fired units. Reduction in the generation available from such resources - whether through capacity retirements, low initial oil inventories, reduction in natural gas availability for power generation, or interruptions in the ability to refuel oil tanks throughout the winter- represents the most challenging circumstances for reliable winter system operations in New York over the coming years, as the transition envisioned by the CLCPA unfolds.

Major increases in renewable generation and other clean energy resources (such as energy storage) into these zones - whether through offshore wind, additional transmission to accommodate incremental power flows from upstate renewables and other resources located outside these constrained regions, or both, can provide significant relief to and reduction in reliance on oil and natural gas for winter operations. The additional gigawatt-hours of generation from renewable resources - particularly offshore wind (injected into Long Island and New York City) - can potentially help to meet some portion of peak demands, but perhaps more importantly can preserve oil and gas for continued operation over an extended cold weather event. Effective and durable energy storage capacity in these zones could also support operations during and around peak winter conditions. Yet the timing for the integration of these resources in the system and to what degree they may be relied on under severe winter conditions is not well known at this time. It will be critically important over the next one to two decades to fully understand and actively manage the impact of the evolving resource mix in New York.

2. Results

As described previously, the analysis begins with a supply and demand snapshot of the winter of 2023/2024, subject to historically severe winter conditions over the seventeen-day period. Over this period, the system is depicted through various combinations of system scenarios and physical disruptions, representing nearly one hundred cases in aggregate. Each case is run through the fuel and energy security model, which generates a detailed set of case diagnostics.[17] For each case the likelihood that the condition postulated would occur was also assessed.[18]

The key results for each case are depicted in Figure ES-4. Figure ES-4 represents the occurrence of potential LOL events across the seventeen-day period as a line chart within each case box, showing the relative magnitude, frequency, and duration of potential LOL events for each case. No line within the box indicates no potential LOL event associated with the case at issue. The most significant potential LOL events are seen for the most severe (and lowest probability) cases - namely, scenario 8 across all physical disruptions (the last column), and physical disruption 11 across all scenarios (the last row).

While Figure ES-4 shows the potential for LOL events, it does not contain an assessment of the relative probability of each case being realized. In Figure ES-5, cases are color coded based on their level of risk, taking into account both the severity of potential LOL impacts and an assessment of the likelihood of the conditions postulated in each case coming to fruition. The designation “LI Only” in a cell indicates that the identified, potential LOL events only occur on Long Island (zone K). With respect to the color coding, each case is categorized as follows:

- **Green:** The case leads to few or no potential LOL events, and none greater than 100 MW, and/or the probability of the combined scenario/physical disruption being realized is *extremely low, well outside* the types of system conditions and contingencies typically considered in operational assessments.

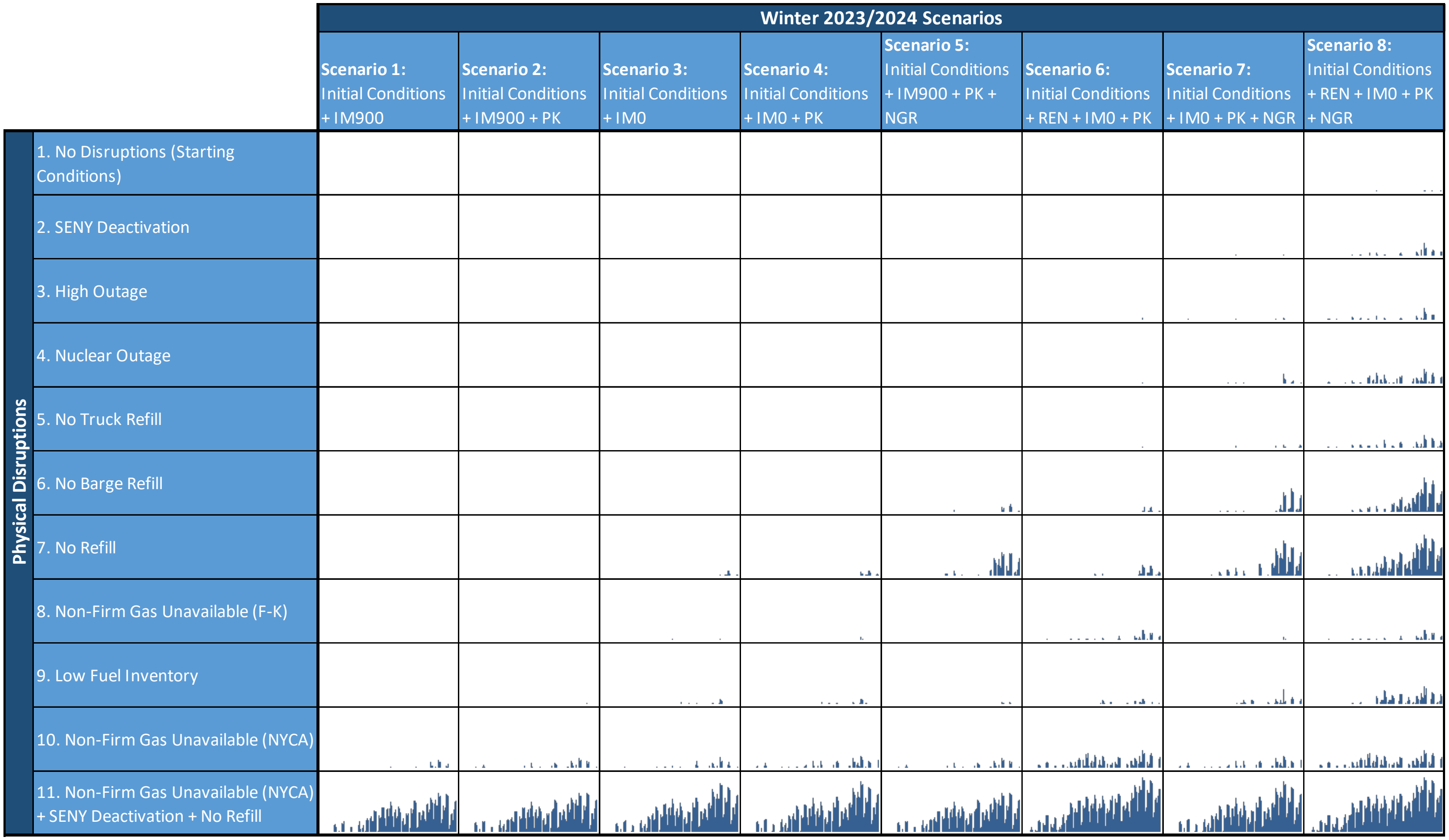
[17] The detailed results across all cases are further described in Section VI, with the detailed diagnostics for each case presented in Appendix E.
[18] See Section VI for a detailed description of the method for assessing case probabilities.

- **Yellow**: The case leads to potential LOL events greater than 100 MW but none greater than 1,500 MW with such events generally being of moderate duration or frequency, and the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Orange**: The case leads to potential LOL events greater than 1,500 MW, but the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Red**: The case leads to potential LOL events greater than 1,500 MW, and the probability of the combined scenario/physical disruption being realized is *on the order of* (or similar to) the types of system conditions and contingencies typically considered in operational assessments.

The purpose of combining assessments of both probability and consequence in this way is to focus in on a subset of cases that (a) have the potential for significant reliability risks that may not otherwise be addressed, mitigated or eliminated through existing or easily-implemented actions, and (b) are probable enough to merit further attention and consideration of whether additional mitigating action is warranted (e.g., enhancements to operational procedures or market designs). While this process necessarily involves the application of professional judgment and the use of assumed metrics of impact, the transparent nature of the analysis and comprehensive set of diagnostics allows entities to develop their own interpretation of results, to the extent they differ from those contained herein.

It is useful to observe the results across physical disruptions for a given scenario, and *vice versa*. In this way it is possible to see the specific impact of a given set of system conditions or disruptive event on reliability risks, or to gauge the magnitude of impact from one case to another, all else equal. For example, scenario 7 contains a cross section of results that vary in location, probability, and impact across the physical disruptions. Figure ES-6 shows how both the severity of potential LOL events (in MW, the y -axis) and duration across the 17-day period (in hours, the x- axis) vary as the case steps from no disruptions through the various assumed physical disruption events. Similarly, Figure ES-7 shows how potential LOL event severity and duration vary across scenarios for the low initial fuel inventory physical disruption.

Figure ES-4: Potential LOL Events by Case



Note: The scale of the axes are equal in all cells. The y-axis is set to have a maximum of 16,000 MW.

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

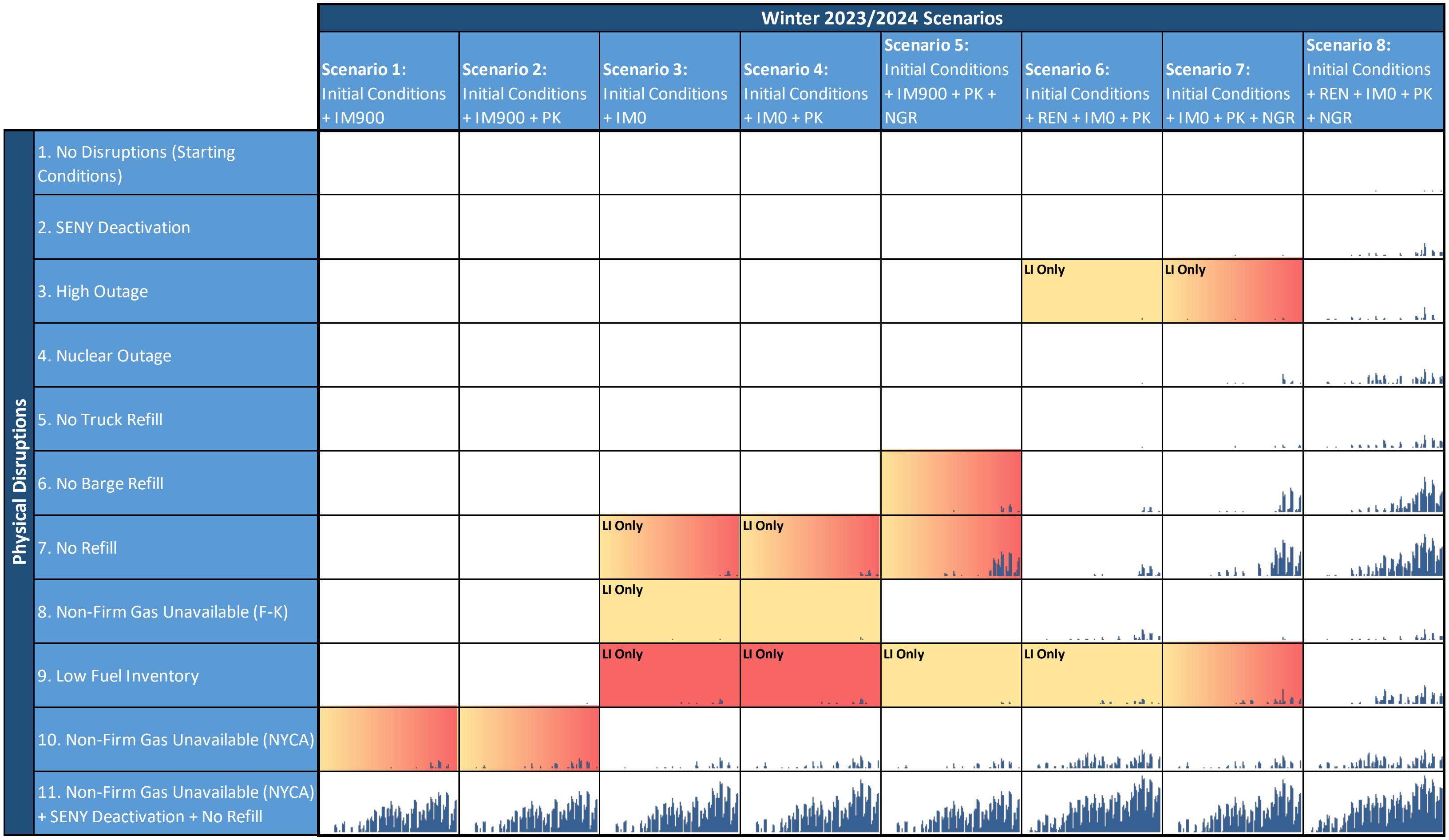
IM900 = 900 MW Capacity Imports.

IM0 = 0 MW Capacity Imports.

PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

Figure ES-5: Heat Map of Reliability Risks



Note: The scale of the axes are equal in all cells. The y-axis is set to have a maximum of 16,000 MW.

Combined Assessment: Based on qualitative assessments of Probability, Consequence, and ease of Mitigation, grouped as follows:

- Consequence 0-100 MW or probability extremely low (far outside normal operational assessments)
- Consequence 100 - 1,500 MW, of moderate duration/frequency, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability on the order of normal operational assessments

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.
IM900 = 900 MW Capacity Imports.
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NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

Figure ES-6: LOL Duration Curves for Scenario 7, All Physical Disruptions

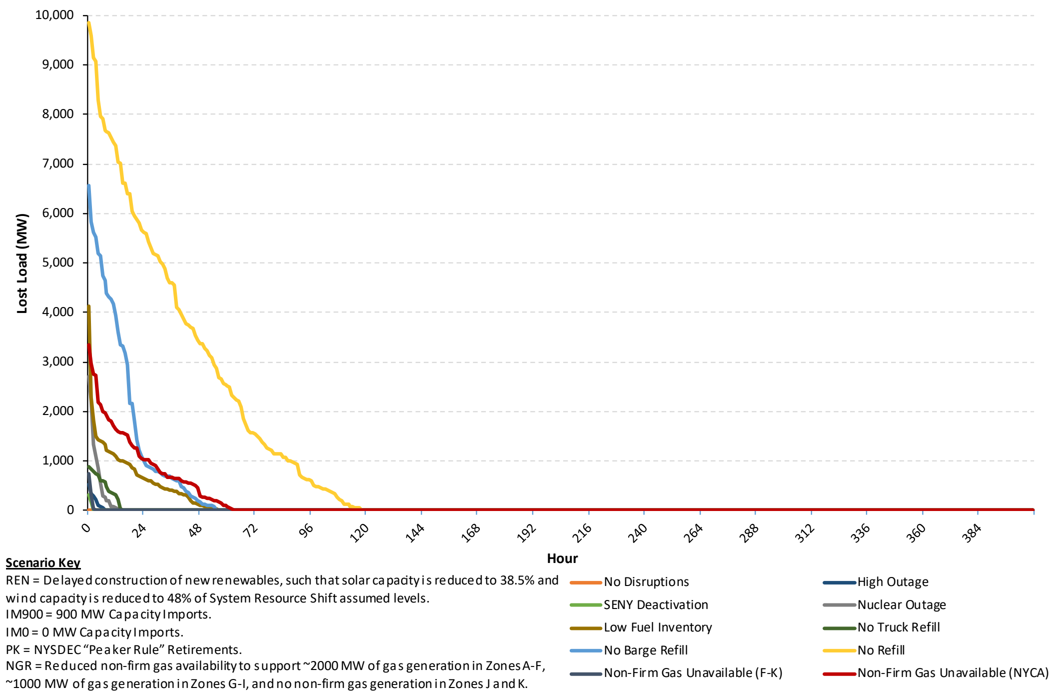
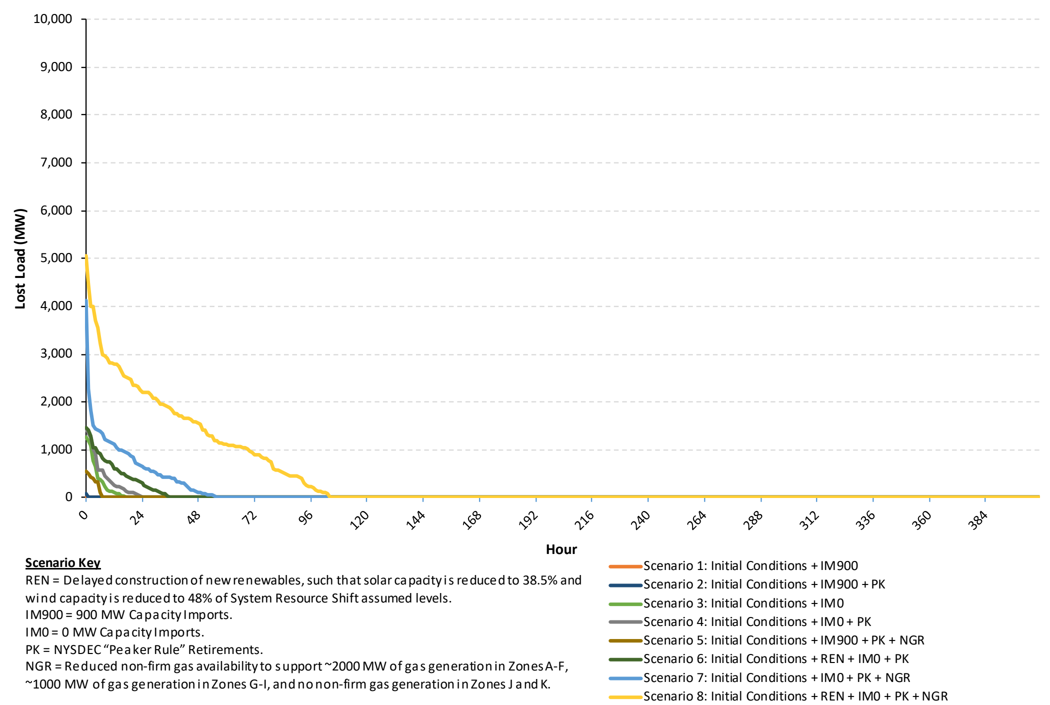


Figure ES-7: LOL Duration Curves for Low Initial Fuel Inventory Disruption, All Scenarios



3. Observations

Based upon the review of detailed case diagnostics, the following observations with respect to energy and fuel security in New York have been identified:

Based on the resources and operating capabilities assumed in the study, the New York power grid is well equipped to manage energy/fuel security risks. The overall risk associated with fuel and energy availability during winter months is relatively low. Across the cases reviewed that *do not* involve significantly adverse assumptions about future resource configurations or major disruptive events, power system reliability is not jeopardized. This is true even though the starting point for the analysis represents severe winter conditions. With the continued operation and availability of most of the assets currently expected to be in place in the winter of 2023/2024, the New York power grid contains sufficient diversity and depth of fuel supply to support reliable winter operations. This result is consistent with the historical operating experience in recent past winters, including during severe weather conditions.

NYISO has already taken many steps to address potential risks associated with fuel and energy security concerns. Part of the reason New York is well positioned is because many steps have already been taken to monitor, evaluate, and address potential risks associated with the availability of fuel and responsiveness of generating assets. This includes a variety of practices and requirements intended to ensure continuous monitoring of assets and fuel inventories, and visibility into the operations, capacities and constraints of interstate pipelines and local natural gas LDC systems; coordination of the timing of natural gas and electricity markets and the ability of generators to account for fuel opportunity costs in offers; the institution of requirements on downstate generators related to the capacity to operate on multiple fuels and switching fuels if and as needed based on prevailing temperature conditions; the incorporation of dual-fuel requirements for peaking plant technologies in the setting of the ICAP Demand Curves for downstate capacity regions (zones G-K); and the adjustment of reserve requirements statewide and downstate to reflect reserve needs in system operations. The set of steps already taken through changes in market rules and/or operating procedures have the effect of both increasing operator awareness of the risks and instituting requirements and financial incentives supporting the availability of fuel and the operation of assets important for reliable winter operations.

Significant potential LOL events appear in cases involving reduced operation of oil-fired generating assets, particularly in the downstate regions. New York encounters meaningful reliability challenges when initial inventories of oil are low, and/or the ability to replenish oil supplies is constrained by weather or other factors. In fact, the vast majority of potential LOL events occur in cases subject to physical disruptions associated with low initial fuel oil inventories at oil and dual fuel power plants, and/or reductions in or elimination of oil refill capability (truck, barge, and both). In these cases, potential LOL events tend to arise later in the seventeen-day modeling period as inventories are used up and not replenished.

Significant interruptions or reductions in the availability of natural gas for power generation can introduce challenges for reliable operations. Disruptions involving the loss of non-firm natural gas for power generation NYCA wide, or (to a lesser extent) only in zones F-K, lead to potential LOL events under most scenarios. The loss of non-firm gas across the state introduces significant potential LOL events in all scenarios; the loss of non-firm gas (for power generation) limited to zones F-K does not by itself cause potential LOL events unless other system limitations arise (i.e., import reductions alongside the potential retirement of units in response to the proposed "peaker rule," reduced oil refill capability, or delayed deployment of new renewable resources).

Dual fuel capability - with oil as a backup fuel to natural gas - is vital for maintaining reliability. Taking into consideration the demand for natural gas by LDCs for serving retail needs, there simply is not enough gas available for power generation downstate under prolonged, severe cold winter conditions to ensure reliable operations, absent the ability of dual-fuel units to switch fuels. While these resources may operate economically - and to the advantage of electricity consumers - most of the year on available non-firm supplies of natural gas, under severe cold weather conditions LDC demand and other firm natural gas transportation commitments (including for deliveries to neighboring regions) reduce available natural gas for power generation to levels below that needed for reliable system operations, absent the ability to switch to oil. Maintaining adequate dual fuel and other oil-fired operating capability is critical to reliable operations during averse winter conditions, especially in the downstate region.

A majority of circumstances leading to potential LOL events are constrained to Long Island. All cases with potential LOL events greater than 1,500 MW and probability of occurrence conceptually similar to normal operational assessments occur on Long Island only. Moreover, of the fifteen potential LOL events exceeding 100 MW across all cases, nine occur on Long Island only. Long Island's vulnerability stems primarily from the combination of limited import and internal transfer capability, and a particular reliance on oil-fired capacity. Maintaining adequate imports and dual fuel (and other oil-fired) operating capability are critically important to reliable winter operations on Long Island.

Meeting the state's renewable and clean energy resource goals can provide valuable reliability support, and this may be particularly true with respect to offshore wind. The results demonstrate that delayed realization of renewable resource additions (as compared to the 2017 CARIS Phase 1, System Resource Shift case levels that are assumed under initial conditions) can lead to potential LOL events that would not otherwise occur when combined with other adverse system conditions. Moreover, additional analysis was undertaken to assess the specific impacts of adding the approximately 1,700 MW of offshore wind recently announced by the State as having been selected as winners of the first offshore wind solicitation conducted by NYSERDA (with roughly half injected into Long Island and half injected into New York City), since these new projects may be in service not long after the winter of 2023/2024. These additions made meaningful contributions to reducing potential LOL events in downstate New York, and particularly on Long Island. The connection of this large quantity of energy directly into New York City and Long Island primarily helps preserve limited oil and natural gas for supporting reliable operations later in the modeled severe cold weather period.[19] Similarly, a review of certain cases with limited magnitude and duration of potential LOL events could be eliminated through the operation of additional energy storage capacity in targeted locations.[20]

Over the longer term, the potential magnitude and pace of change to the resource fleet stemming from requirements under the CLCPA may be of far greater importance for evaluation than the considerations, scenarios and physical disruptions evaluated in this fuel and energy security study with respect to winter operational risks. The fundamental changes envisioned by the CLCPA suggest that the power system will play a critical role in decarbonization of the state's economy, with at least two fundamental shifts that will affect fuel and energy security during winter months. The first involves the potential electrification of transportation, heating and other sectors which may be needed to achieve the required GHG reductions in those sectors at the lowest possible cost to consumers. This could significantly expand and change the demand for electricity within New York State, and in particular in the downstate load centers that are most susceptible to winter energy security risks. The second is the *contemporaneous* decarbonization of the electric sector itself - requiring that 70 percent of all

[19] Our modeling of these scenarios uses generic offshore wind generation output profiles for the northeast, which are not based on any actual operating experience to date. See discussion in Appendix B.7.

[20] As described in Section III, the model assumes 350 MW of new energy storage in the winter of 2023/2024.

electricity be met through renewable generation *within roughly ten years* (by 2030), and that all electricity be provided by zero carbon resources within approximately twenty years (by 2040).

The potential for rapidly expanding demand for electricity combined with dramatic reductions in fossil-fired generation - including presumably the oil- and gas-fired generation that is currently critical for winter system reliability in the downstate region - warrants careful consideration around how to manage this transition from the perspective of reliable winter operations.

The results of the fuel and energy security assessment point to a number of options that may be considered by NYISO and stakeholders. It is premature to point to a specific set of recommended actions that flow from the fuel and energy security analysis described in this report. This is because the issue first warrants a deliberative review by NYISO and stakeholders of the potential consequence of cases with potential LOL events, their likelihood of occurrence, the potential ability/feasibility and cost associated with mitigating or eliminating the risks, and a careful weighing of the benefits and costs of taking specific actions to address them - whether through NYISO operating procedures, targeted resource or infrastructure additions, administrative actions by the state's electric and/or natural gas utilities, or changes to NYISO's wholesale markets. A full assessment of the costs and benefits of addressing risks arising under various cases analyzed is beyond the scope of this report.

4. Options

From Analysis Group's perspective, it is not clear that the magnitude and likelihood of the risks identified warrant a major NYISO-wide market design effort at this time; the most important challenges are associated with scenarios or disruptions that have a relatively low probability of occurrence, and/or are geographically concentrated on Long Island (an area at the forefront of development of new offshore wind and energy storage resources). Nevertheless, there are a wide range of potential other options to consider that flow from the results of the analysis and the key levers driving circumstances that lead to potential LOL events, the experience with winter fuel and energy security efforts in other regions (e.g., ISO-NE and PJM), and the specific circumstances in New York. Potential options include:

Continued and expanded monitoring and analysis. The impact of severe winter conditions on power system operations in New York is highly dependent not only on the availability of fuel for generating resources, but on the portfolio of resources available, the level and shape of demand under winter peaks, and the various disruptions or contingencies that may occur during cold weather conditions. Continued and expanded monitoring of these conditions represents a clearly valuable endeavor for reliable system operations. For example, the reliance in New York on the flexibility afforded by dual fuel capability, particularly downstate, suggests continued or expanded vigilance in monitoring the practices of generating asset owners with respect to establishing initial winter fuel oil inventories and executing pre-season or in-season contracts with fuel oil suppliers for the reliable delivery (by barge and/or truck) of replenishment fuel on regular and as-needed bases. Moreover, a key uncertainty in the analysis is the actual expected availability of natural gas to support power generation under severe cold weather conditions. NYISO should continue to interact with interstate pipeline operators and the state's natural gas LDCs, and conduct analysis based on available data, to maintain an up-to-date understanding of the changing circumstances of natural gas infrastructure, LDC demand, and likely contractual flows out to neighboring regions.

Focus on the possible impacts of potential retirements in response to the proposed "peaker rule." As revealed in the modeling results, potential retirements in response to the proposed "peaker rule" could have detrimental impacts on winter system reliability if the capacity is not sufficiently replaced with development that can provide the same or similar level of energy and reserve contributions during winter operations. As NYISO evaluates the overall possible reliability impacts of potential retirements and resource fleet changes in response to the proposed "peaker rule," particular attention should be directed to assessing impacts on fuel and energy security in the state.

If continued monitoring indicates the potential for reliability risks related to fuel inventories in the future, further assess the adequacy of incentives for appropriate pre-season fuel oil inventory levels and/or replenishment arrangements. The current operational capability of oil-fired capacity downstate is critical to winter power system reliability in New York. NYISO already monitors inventories, use and replenishment for these units. Moreover, certain units are subject to mandatory oil-burn operations under specified temperature and/or gas system conditions. Nevertheless, given oil's importance, if the continued monitoring of fuel inventories identifies reductions in inventory levels in the future that may pose reliability risks to winter operations, NYISO and its stakeholders may want to evaluate the adequacy of current incentives for establishing appropriate pre-season inventory levels and replenishment contracting arrangements.

Review the potential for geographically-targeted development of new renewable and energy storage resources required or incentivized through implementation of the CLCPA. There is little doubt that there will be a major expansion of advanced low carbon energy technologies over the next ten years. To the extent that winter fuel and energy security risks tend to be concentrated in downstate zones, NYISO may consider evaluating how the interconnection or installation of new renewable and energy storage resources in specific zones or locations on the bulk power system could provide ancillary winter reliability benefits. For example, an assessment of the magnitude, frequency and duration of potential LOL events in specific localities, and under plausible system conditions, could identify particular value associated with energy storage resources that meet certain technical specifications (size, discharge rate, and duration) that could mitigate or eliminate identified reliability risks. In a similar vein, to the extent the CLCPA warrants expansion of transmission system infrastructure (e.g., to move more renewable resources from upstate to downstate), NYISO could consider how to best plan for and design transmission expansion in a way that mitigates potential downstate fuel security issues.

Proactive scenario analysis of the potential impacts of the CLCPA. As noted previously, the state of New York is embarking on a period of unprecedented change in many of the critical demand and supply realities in the state; this suggests value in a proactive reliability-focused scenario assessment of New York's first ten years of CLCPA implementation, reviewing (a) potential changes in the magnitude and shape of power demand across all seasons under postulated scenarios of electrification of transportation and heating sectors; (b) the likely quantities, technical parameters, and interconnection locations of specific grid-connected and distributed renewable and energy storage resources through 2030; (c) the shape (or hourly generation profile) and effective load carrying capability of grid-connected and distributed solar, onshore wind, and offshore wind resources; and (d) the impact of these changing demand and supply hourly profiles on the residual resources needed to maintain power system reliability.

Continuous updating and refinement of energy and fuel security modeling. The results demonstrate that the flexibility afforded by dual fuel capability, particularly downstate, is of critical importance to reliable winter operations. The importance of this capability is expected to persist throughout the ongoing transition of the New York's resource fleet. The results of the analysis also highlight the potentially significant impacts of timely development of new renewable resources. In light of the ongoing transition of the resource fleet, the NYISO should consider continuing the development, refinement, and application of the fuel and energy security model as a tool for continued assessment of winter operational risks as the system and circumstances change over time. For example, the NYISO should consider periodic refreshing of the analysis herein (or certain key aspects thereof) to account for changes in system conditions over time. The NYISO should also consider using the results of this analysis and the capability provided by the fuel and energy security model to identify certain key changes that could serve as leading indicators of potential future reliability and/or fuel security concerns (e.g., identifying the magnitude of dual fuel capability losses that can be sustained before adverse impacts to reliable winter operations arise). Such indicators could be used as part of ongoing, proactive monitoring to identify changes in system conditions that would trigger a need for engaging with stakeholders to assess whether further mitigating action is warranted, and, if so, identifying and evaluating potential remedial options.

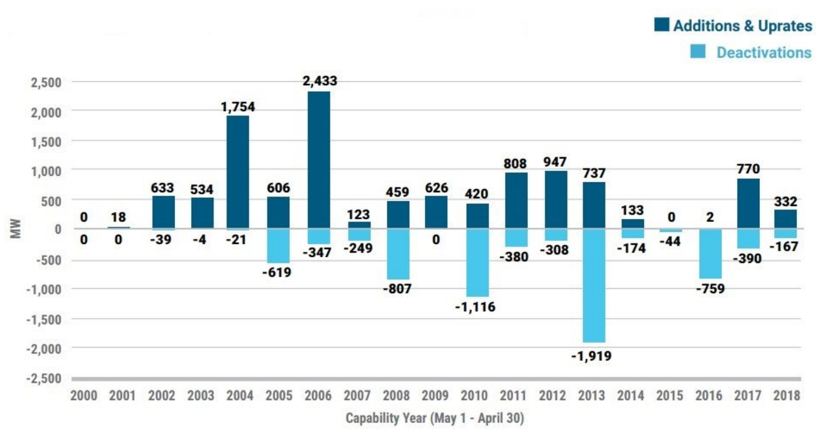
II. Introduction and Purpose

A. Overview

The NYISO is responsible for the reliable planning and operation of the state's bulk power system and the design and administration of the state's competitive wholesale markets. Over twenty years of operations, the NYISO has overseen constant improvements in system reliability and efficiency, power market competitiveness, and consumer costs, while addressing - from both planning and operational perspectives - continuous changes in the infrastructure, fuels, and policies that drive evolution of the power grid. Two key factors have dominated this evolution in recent years, a trend that is likely to amplify and accelerate in years to come. The first is the emergence of natural gas - with the arrival of shale gas - as the fuel of choice for new generating infrastructure development; the second is the march towards decarbonization of the state's economy driven by state policy and, in part, by significant declines in the costs of certain renewable resource options.

These changes have significantly altered and affected the state's generation fleet, and have driven the state to greater dependence on natural gas and renewable resources for power system operations. As seen in Figure 1 and Figure 2, since 2000, over 7,000 MW of existing generation resources have retired or suspended operation in New York, including nearly all coal-fired capacity, while over 11,000 MW of capacity from new generating units and unit upgrades have been added - largely gas fired or dual-fuel units with gas as the primary fuel, and renewable resources (wind and solar).[21] In terms of annual generating capability, since 2000, the contribution of production capability from units with natural gas as the primary fuel has increased from 47 percent to roughly 60 percent.[22]

Figure 1: Additions, Uprates and Deactivations (Nameplate Capacity)



Over this period the increased use of natural gas in New York has contributed to meaningful consumer and public health benefits, as both the price of electricity and the emissions associated with power system operations have declined.[23] Achievement of these benefits have been driven mostly by the displacement of older, less efficient and more polluting fossil fueled generation with newer, more efficient and less polluting natural gas-fired generation and renewable resources. Generating resource diversity of all types - in fuel source, mode of operation, geography, size, etc. - can contribute to the resilience and reliability of the power system. It is thus important to continually review a system's mix of generating resources and consider whether the collective attributes of the bulk power system introduce or mitigate reliability risks. The increased dependence on natural gas and weather-dependent renewables does not *necessarily* increase the challenges associated with reliable system operations, and does not by definition increase

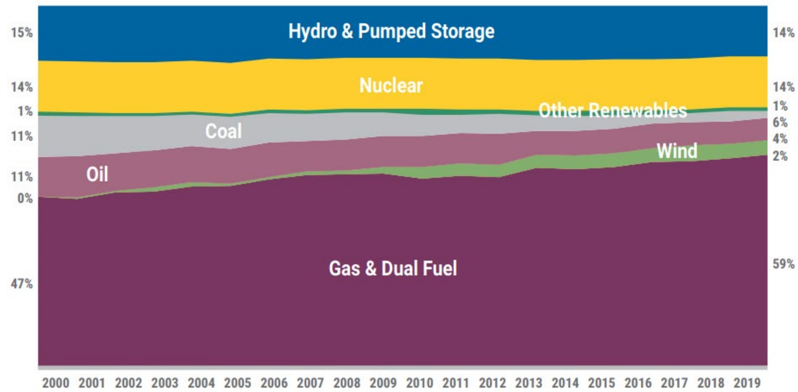
[21] NYISO, Reliability and a Greener Grid, Power Trends 2019, pp. 17-18 (hereafter "NYISO Power Trends 2019"), available at https://www.nyiso.com/documents/20142/2223020/2019-Power-Trends-Report.pdf/0e8d65ee-820c-a718-452c-6c59b2d4818b?t=1556800999122

[22] NYISO Power Trends 2019, page. 30.

[23] NYISO Power Trends 2019, page. 33.

the risks associated with maintaining system reliability in the winter. Nevertheless, in light of the current circumstances and context - involving increased use of natural gas and a potentially rapidly-evolving power system that to-date has been strongly dependent on fossil-fired generation (particularly in the downstate region - see Figure 3).[24] - NYISO asked Analysis Group to undertake an assessment of potential fuel and energy security risks, with a focus on winter conditions.

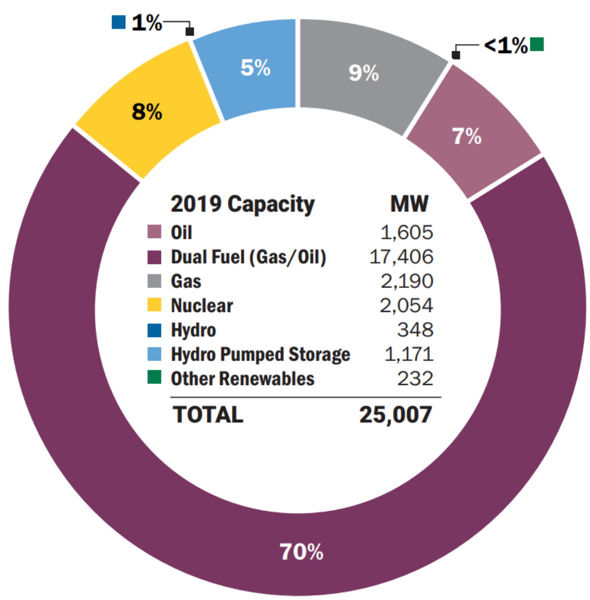
Figure 2: New York State Fuel Mix Trends: Capacity 2000-2019



Several factors suggest that increased monitoring and analysis of the impact of increasing dependence on natural gas and weather-dependent renewables on the reliable operation of the NYISO power grid are warranted:

- Increased dependence on any fuel generally has the potential to decrease the diversity of power system infrastructure, and reduce the reliability benefits that flow from greater diversity (in the fuel source, location, size, and operational modes of power system generating resources).
- The growth in use of natural gas and weather-dependent renewables has coincided with the retirement of generating capacity operating on other fuels, and the potential continued retirement of oil, coal, and/or nuclear capacity.
- The state's continued efforts to reduce emissions of harmful pollutants and decarbonize all sectors of the economy - most recently through the enactment of the CLCPA - have potentially two significant outcomes: (1) a continued decline in oil-fired and other fossil-fired generation that is currently critical for reliable winter system operations downstate, and (2) a potentially major increase in (and change in the shape of) demand for electricity, due to potential electrification of the building, transportation, and other sectors in the economy. This electrification is likely needed to meet the CLCPA's economy-wide GHG reduction requirements. Despite the need to reduce fossil fuel combustion in total across all sectors to meet the state's GHG emission reduction targets, fossil-fired generation (including natural gas) will be needed for reliable power system operations throughout this transition, to support

Figure 3: Downstate Generating Capacity, Zones F-K



[24] NYISO Power Trends 2019, page. 26.

electrification of other sectors (and associated increases in electricity demand), and help manage the greater variability of increasing quantities of weather-dependent renewable generating resources. It is difficult to forecast what the role for gas-fired generation is over the next couple decades; yet it seems possible it could take on greater importance for power system reliability in the near to intermediate term.

New York is not alone in facing these challenges or in assessing the risks to system operations associated with changing resource sets, increased reliance on natural gas and renewable resources, and policies aimed at accelerating and amplifying the deployment of renewable and other clean energy resources. NYISO's neighboring U.S. markets - ISO-NE and PJM - have also recently examined the issue of winter fuel security through their own fuel security studies released in 2018.[25] The studies conducted by ISO-NE and PJM focused on fuel security-related reliability risks, and considered many similar types of future scenarios that could negatively impact future reliability. Yet the studies come to different conclusions about risk. The ISO-NE report concluded that the region could be subject to significant loss of load events under a variety of future conditions, whereas the PJM analysis concluded that there is no imminent threat to reliability and fuel security in their region. Components of the ISO-NE and PJM reports are further described in Appendix A.

The state of New York has witnessed significant changes over the last decade and a half, driven primarily by the emergence of natural gas as the fuel of choice for electricity generation. Going forward, the state is embarking on an ambitious and challenging period of transition - one that may require an unprecedented level and pace of change in power system infrastructure and operations to achieve the CLCPA-mandated GHG emissions reductions in all sectors of the economy. In this context, it is a good time for NYISO, electricity market participants, and stakeholders to consider the current risks - if any - associated with winter system operations, and to explore the key factors that will likely drive how these risks may change over time.

B. Purpose of the Study

The mix of fuels used to generate electricity affects both the reliability and resilience of the bulk electric system. A balanced array of resources enables the system to better address issues such as price volatility, fuel availability and stressed/abnormal operating conditions. New York's electric generation fleet has historically been comprised of a relatively diverse mix of fuel types.

The decline in natural gas prices, technological advancements, environmental and economic considerations, and public policies are driving significant changes to the portfolio of supply resources in New York. These conditions highlight the potential for future challenges to arise in meeting electric system demands under certain stressed conditions such as prolonged cold weather events and/or fuel supply or transportation availability constraints or disruptions.

In response, the NYISO engaged Analysis Group to conduct a forward-looking assessment of the potential risks to New York associated with wintertime power system operations. Analysis Group was tasked with assessing winter fuel and energy security risks, and identifying key factors that will affect the likelihood and potential severity of any identified risks.

The analysis was not designed to focus on the questions of economics or consumer costs, and does not involve the use of production cost or economic modeling. Instead, this is a deterministic scenario-based winter reliability

[25] ISO New England, "Operational Fuel-Security Analysis," January 17, 2018, available at https://www.iso-ne.com/committees/key-projects/implemented/operational-fuel-security-analysis. PJM Interconnection, "Fuel Security Analysis: A PJM Resilience Initiative," December 17, 2018, available at https://www.pjm.com/committees-and-groups/issue-tracking/fuel-security.aspx.

assessment. It presents an evaluation of potential reliability risks and impacts under *severe* winter conditions and *adverse* circumstances regarding system resources, physical disruptions, and fuel availability. The objective is to better understand under what combinations of severe winter weather and highly adverse system conditions the reliability of the power system might be vulnerable, and what the potential impacts could be under such conditions.

While the model described herein is rooted in historical circumstances and current demand and resource expectations, where possible the report seeks to have an eye towards the unprecedented changes underway in New York. New York's expectations for the future transition of the power grid - as evidenced by requirements set forth in the CLCPA and many other policies established by the state legislature and regulatory agencies in recent years - involves rapidly declining reliance on fossil fuels, and increasing reliance on renewables, other low-/no-carbon resources, and storage. Demand for electricity may substantially increase (and potentially significantly change in shape) over the next two decades, assuming electrification represents an efficient and least-cost path to decarbonization of transportation, building, and other sectors of New York's economy. Yet at the same time, the CLCPA requires in the electric sector achievement of 70 percent renewable generation by 2030, and 100 percent zero-carbon generation by 2040.

C. Overview of Analytic Method

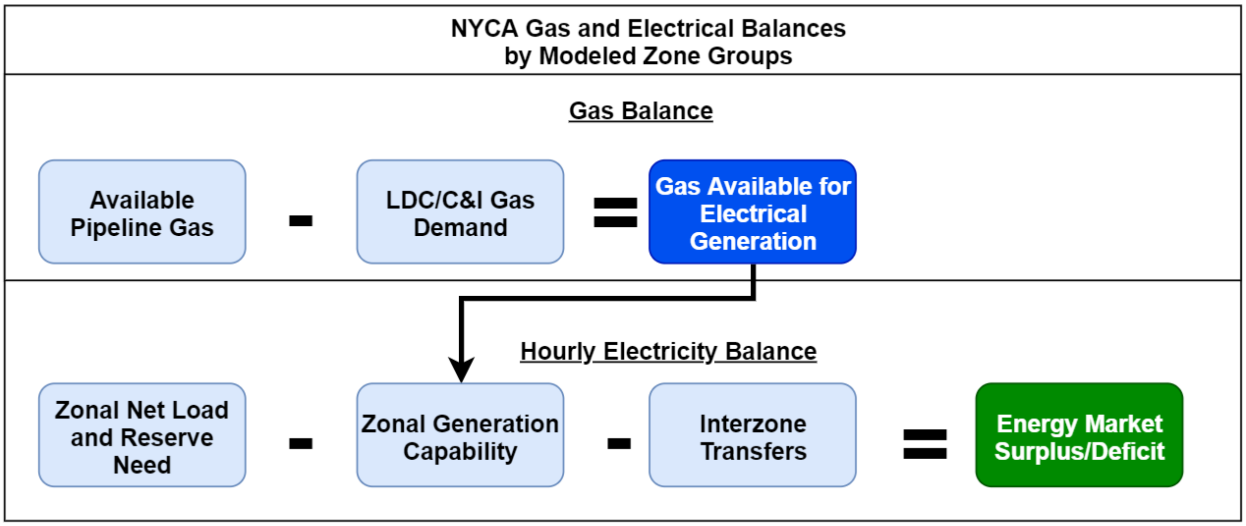
Analysis Group developed and applied its fuel and energy security model to comprehensively assess the risks of wintertime operation under adverse conditions, with specific application to the NYISO power system. Figure 4 presents at a high level the analytic components of the fuel and energy security model, used to generate results for all cases. As the schematic shows, there are two major elements of the analysis. First, historic data are used to model a balance of the natural gas system in New York, in order to determine the availability of natural gas to support electricity generation at natural gas-fired power plants. With this data, the model then undertakes a structured, locational balance of supply and demand on the electric system on an hour-by-hour basis over the seventeen-day modeling period.

The end result of this modeling effort is a set of detailed diagnostics for each case, describing potential loss of load events (if any) in terms of magnitude (MW of potential deficiency), frequency, and duration over the modeling period.[26] These results are combined with an assessment of the likely probability of these consequences being realized, based on a qualitative review of the various system conditions and physical disruptions included in each case. The purpose of combining assessments of both probability and consequence in this way is to focus in on the subset of cases that (a) have the potential for significant reliability risks that may not be addressed, mitigated or eliminated through existing or easily-implemented actions, and (b) are probable enough to merit further attention and consideration of whether mitigating action is warranted.

The next section provides a more detailed description of the analytic method, model components, and data and information sources used in the analysis. This is followed by a summary of results.

[26] The model also identifies circumstances where there is no loss of load, but conditions are tight enough to lead to a reduction in energy-only exports, activation of SCR/EDRP, reduced reserves, or all of the above. See Sections III and V.

Figure 4: Structure of Fuel and Energy Security Analysis



III. Analytic Method

A. Framework for Fuel and Energy Security Analysis

Analysis Group' fuel and energy security model is a deterministic, scenario-based assessment of a future year's winter system operations subject to a variety of scenarios (different assumptions regarding future system topology) and physical disruptions (primarily episodic changes to the system affecting fuel and resource availability). An initial set of system conditions is identified that define weather, electric and gas demand, and gas and electricity transmission/transportation capacities. Scenarios and physical disruptions are then combined to define "cases," which are run through the fuel and energy security model to identify any risks associated with winter operations under these conditions.

The starting point for the analysis is expected system conditions for a future winter season - the winter of 2023/2024. System demand, supply resources, and transfer capabilities are based on previously-vetted NYISO study assumptions, including the 2017 CARIS Phase 1 analysis. The energy and fuel security model studies an extended period of cold weather based on analysis of 25 years of historical weather data. The modeled cold weather event spans seventeen days of frigid winter conditions, including a historic three-day severe cold weather event (occurring on days six through eight of the event). Figure 5 contains a detailed schematic of the fuel and energy security model logic and data sources.

The fuel and energy security model includes the following data and modeling steps, conducted where appropriate for specific locations (zones or combinations of zones) within the state:

1. <u>Weather</u>: Identify severe winter conditions based on historical winter weather data, and use this to identify an appropriate extended "severe cold weather event" period in terms of length, daily heating degree days, and including a short period of very severe weather within the duration of the extended event.
2. <u>Electric and Gas Demand</u>: Using historical data, establish locational relationships between temperature (heating degree days) and two factors affecting natural gas use and availability: (a) LDC retail gas demand and (b) electric load.
3. <u>Fuel</u>: Using historical data reported by generation resources to the NYISO, evaluate the likely inventories and refill capabilities for oil-fired (including dual fuel) units.
4. <u>Pipeline Capacity</u>: Using public data from EIA, interstate pipelines, and other sources, estimate the capacity of natural gas infrastructure in New York to deliver natural gas for meeting both LDC retail gas demand and power system needs, net of what is currently known to be committed for export to surrounding states/regions.
5. <u>Natural Gas System Balance</u>: Use items #2 and #4 to determine a *natural gas system balance*, approximating the availability of non-firm natural gas for power generation on a daily basis over the extended severe cold weather event.
6. <u>Power System Resources</u>: Combining estimates from #5 and data on non-gas resource availability, identify the resources expected to be available for electricity generation under the modeled winter conditions, and stack order them based on likely output, availability of fuel, and operational efficiency, to determine total potential generation and transfers between locations in New York on an hourly basis over the extended severe cold weather event.

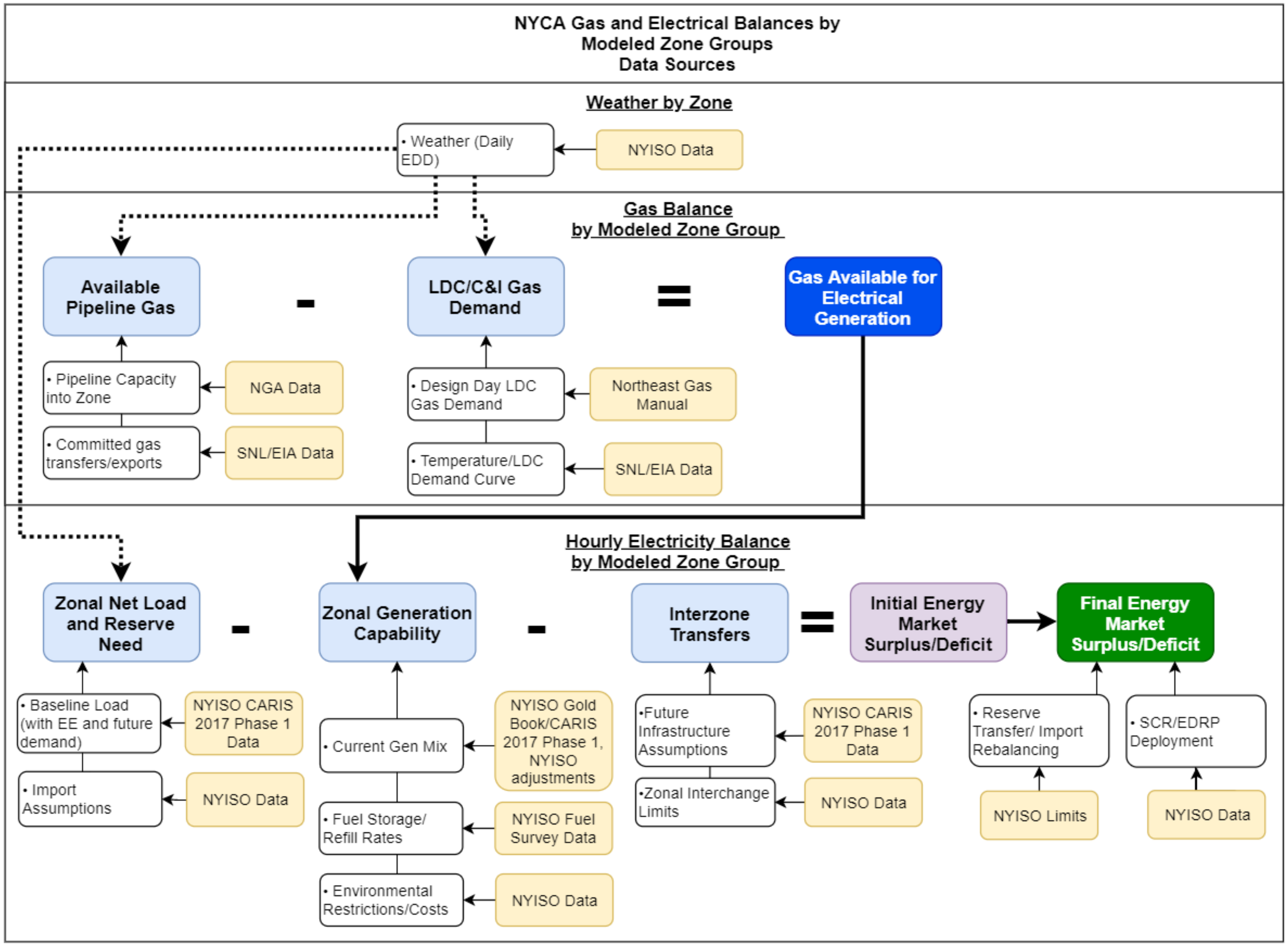
7. NYISO Actions: Identify hours where NYISO actions to reduce energy-only exports to New England or activate SCRs/EDRP are necessary to meet load or maintain reserves, and model the effect of such actions.
8. Electric System Balance: Compare the hourly zonal demand for energy with the available electric generation (and transfer capability between regions within New York) to identify the *electrical supply/demand balance* on an hourly basis.
9. Case Specification: Identify relevant variations in overall system and fuel infrastructure (scenarios), and potential unexpected events (physical disruptions), to determine a range of possible futures (cases) to analyze through the model.
10. Reliability Assessment: Run the model for each case; identify the magnitude, frequency and duration of any periods where available generation was potentially insufficient to meet demand plus reserves over the duration of the extended severe cold weather event.

As noted, the model was run for a wide range of cases that vary along two dimensions: "scenarios" represent potential variations in the configuration of resources, fuel availability and power transfers in the future year, and "physical disruptions" primarily identify episodic conditions that do not necessarily reflect permanent system changes (evaluated singularly or in combination). In total, the analysis assessed system performance under nearly one hundred "cases," each representing some combination of the identified scenarios and physical disruptions. A number of additional cases were also run to test the impact of issues identified by Analysis Group or raised in NYISO and stakeholder discussions. For example, the potential impact of adding offshore wind connected into downstate New York was assessed, as was the effect of unrestricted SCRs/EDRP over the entire modeling period.[27] Where relevant, the results of these additional cases are discussed herein.

In the sections that follow, the methods and underlying data used in the model and analyses summarized above are further described. Section B addresses the selection of an appropriate extended severe cold weather event for the winter 2023/2024 period, based on historical winter weather data, and the determination of relationships between the weather data and demand for LDC retail natural gas and electricity in New York State. Next, the various resource assumptions that apply across all cases with respect to generation, transmission, and fuel availability are further described. Following the review of these assumptions, the "dispatch" and intrastate power transfer logic that is applied in running cases is addressed. The final element reviews the metrics used to assess the level of risk associated with case outcomes (in terms of the magnitude, frequency and duration of potential loss of load (or emergency action) events), and the assessment of the likelihood of case outcomes.

[27] The model otherwise assumes a specific level of demand response "fatigue" that limits the availability of SCRs/EDRP to 4 hours of load reduction capability per activation for a maximum of 5 days during the seventeen-day modeling period. See Section III.D.2.

Figure 5: Energy and Fuel Security Model Steps and Data Sources



B. Construction of Winter 2023/2024 Modeling Period and Relationship of Temperature to Demand

The analytic model represents a severe winter weather period during the winter of 2023/2024. The selection of this modeling period was designed to replicate the most severe winter conditions experienced over a sufficiently long event. With the modeling period defined, historical weather data, and corresponding natural gas and electric demand data was used to establish relationships between temperature (effective degree days, or EDD) and daily/hourly demand.[28] This is the first step in the analysis because these relationships are needed to identify, during the extended severe cold weather event modeled:

1) the demand for natural gas from natural gas local distribution companies to serve retail gas demand on a daily basis;
2) the remaining amount of natural gas available daily for use by natural gas and/or dual-fuel power plants; and
3) the hourly demand for electricity.

This section describes the data and analyses used to (1) construct the modeling period based on historical weather data, and (2) estimate associated natural gas and electricity demand patterns.

1. Analysis of Historical Winter Weather Patterns

A critical variable in analyzing winter fuel security concerns is the weather, which drives both electrical load and retail natural gas demand by end-users. The modeling period is constructed to analyze a severe winter weather event lasting 17 days, which represents an extended 14-day cold period and an extreme 3-day "cold snap" (modeled as occurring over days six through eight of the extended event).

To establish an appropriate extended duration cold weather event, historical hourly weather data by zone was provided by NYISO, and analyzed for the years 1993-2018. As seen in Table 1, the period spanning December 25, 2017 through January 8, 2018 was the coldest consecutive 14-day period in the historical data where daily temperatures were in the tenth percentile of wind-adjusted temperatures or lower, with an average temperature across the NYCA of 11.4 degrees F and an average wind-adjusted temperature of -0.8 degrees F.

The fuel security risks caused by extended cold weather may be further exacerbated during short cold snap periods of a few days, when natural gas supply capacity reaches maximum utilization and when fuel oil transportation issues (such as frozen roads or waterways) may interfere with fuel replenishment. Using the NYISO historical data, the period spanning January 18, 1994 through January 21, 1994 was identified as the coldest consecutive 3-day cold snap between 1993 and 2018, with an average temperature across the NYCA of 2.9 degrees F (see Table 2 below).

The temperature profile for the modeling period was constructed by combining the temperatures of the 3-day cold snap with the 14-day cold period, with the cold snap being inserted into the sixth through eighth days of the extended cold weather period.[29] This 17-day modeling period (see Figure 6 below) thus represents an extreme cold weather event equivalent to a historically cold 17-day period from the last 25 years, including the worst-case

[28] Temperature graphs are shown in terms of heating Effective Degree Day (EDD), which is defined as 65 degrees Fahrenheit minus temperature. See National Weather Service, "What are Heating and Cooling Degree Days," available at https://www.weather.gov/key/climate_heat_cool.

[29] The sixth day was selected day to coincide with the first cold "peak" in the historical 14-day cold weather period.

three-day cold snap during that period. Since the purpose of the analysis is to examine fuel and energy security risks under severe winter conditions, this 17-day period is used in all cases as the model baseline for estimates of LDC retail gas demand, availability of natural gas for power generation, and hourly electrical demand.

Table 1: Extreme Weather Events Lasting over 14 Days

Cold Snap Period	Number of Days	Average Wind-Adjusted Temp (F)	Average Unadjusted Temp (F)	% Increase of Avg. Daily Energy Above Winter Baseline
12/19/2000 - 01/05/2001	17	10.6	20.7	3.1%
01/10/2003 - 01/28/2003	18	3.8	15.2	6.0%
01/18/2004 - 02/01/2004	14	2.1	14.6	8.2%
01/14/2005 - 01/29/2005	15	1.2	12.4	10.1%
02/02/2007 - 02/19/2007	17	4.6	17.4	9.0%
02/07/2015 - 02/21/2015	14	3.1	14.0	10.1%
12/25/2017 - 01/08/2018	14	-0.8	11.4	13.3%

Notes:
[1] Wind-Adjusted Temperature is calculated using the Wind-chill formula from Weather.gov, valid for temperatures (T) at or below 50 degrees F and wind speeds (W) above 3 mph: WindChill = 35.74 + (0.6215 × T) - (35.75 × W^0.16) + (0.4275 × T × W^0.16).
[2] Percentage Increase of Avg. Daily Energy Above Winter Baseline is calculated using: ((Average daily system load during cold snap - 50th percentile daily system load for that winter)/50th percentile daily system winter load for that winter).
[3] Daily load calculated by first summing hourly load and then averaging over the period of the cold snap.

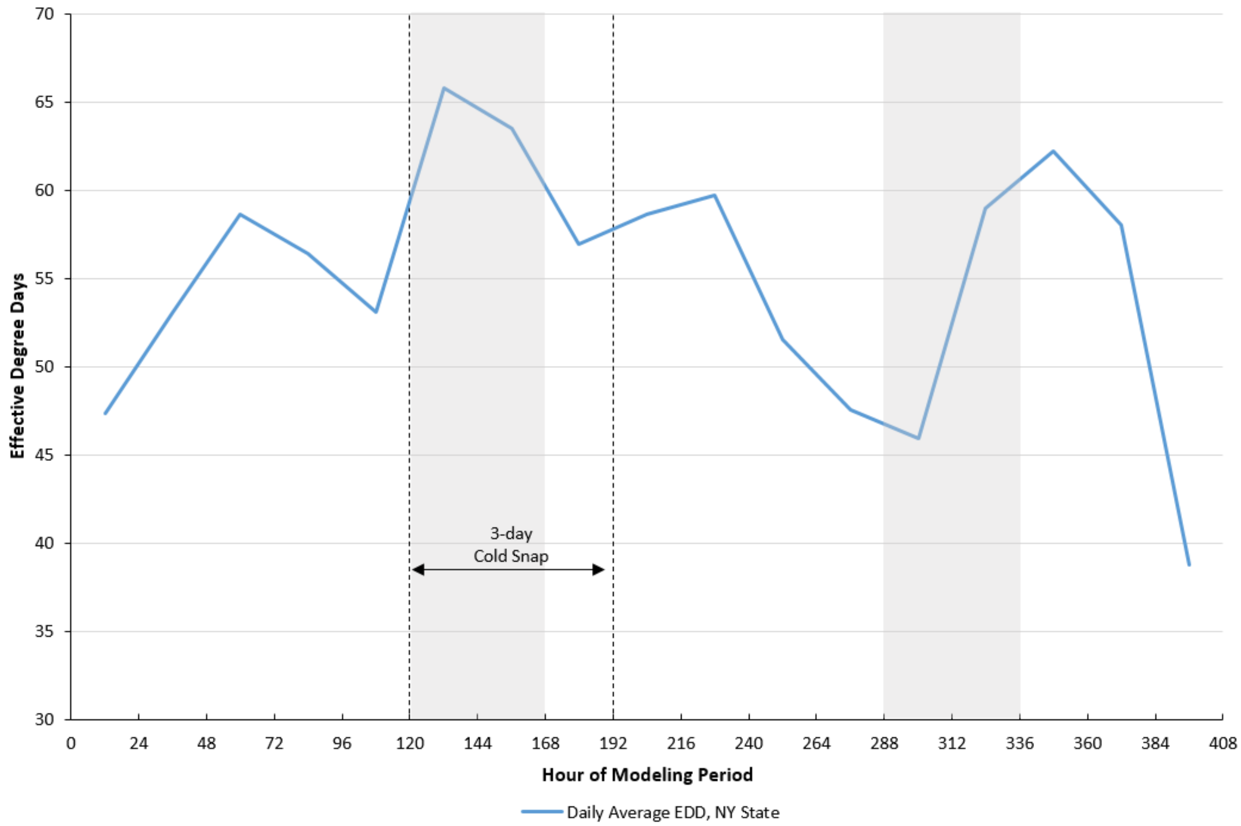
Sources:
NYISO Weather Data 1993-2018; NYISO Hourly Load Data 1993-2018.

Table 2: 3-Day Cold Snaps

Winter	3-day period w/min temperature	Average Temp during 3-day min temp period
1993 - 1994	01/18/1994 - 01/21/1994	2.9
2003 - 2004	01/13/2004 - 01/16/2004	3.4
2004 - 2005	01/20/2005 - 01/23/2005	5.2
2017 - 2018	01/04/2018 - 01/07/2018	5.3
1995 - 1996	01/04/1996 - 01/07/1996	5.8

Source:
NYISO Weather Data 1993-2018; NYISO Hourly Load Data 1993-2018.

Figure 6: Daily Temperatures During 17-Day Modeling Period



Notes:
[1] Weekends are shaded in gray.
[2] Effective degree day is defined as 65 degrees F - Temperature.
Source:
[1] NYISO Weather and Load Data 1993-2018.

2. Relationship of LDC Demand to Weather

A key driver in the analysis and results is the quantity of natural gas generation available to support gas-fired generation during cold winter weather. Under these conditions, New York LDC retail demand for natural gas is at its highest, and firm transportation through New York to external regions (for both LDC retail demand and power generation) is also at its highest. This can constrain the amount of non-firm natural gas available to support electricity generation in New York, having two effects critical to maintaining reliability: (1) it can potentially limit or preclude the dispatch of gas-only units, and (2) it can force dual-fuel units to operate more frequently over the modeling period on oil, drawing down oil inventories and requiring more frequent and more rapid oil inventory replenishment.

The starting point then is to estimate the amount of natural gas available to support electric generation during the modeling period by estimating the consumption by natural gas LDCs under these same winter conditions.[30] This is done by establishing the historical relationship between LDC retail natural gas demand and temperature.[31] With this relationship in hand, the model uses the temperature pattern defined for the extended severe cold weather event to predict daily LDC retail gas demand throughout the seventeen-day event.

Data from three winters (2016/2017, 2017/2018, and 2018/2019) are used to estimate the statistical relationship between LDC retail gas demand and temperature separately for upstate and downstate.[32] Figure 7 and Figure 8 below show these relationships. Next, this modeled relationship is calibrated to LDC retail natural gas demand during the LDC's design day.[33] A gas design day is defined as 65 EDD downstate, and 75 EDD upstate. The statistical models are calibrated to the LDCs' filed design day demand by multiplying the modeled LDC retail gas demand based on the temperature in each day of the modeling period by a scaling factor. The scaling factor is equal to the filed LDC design day capability for all upstate/downstate LDCs divided by the modeled LDC retail gas demand at the design day temperatures of 75 EDD for upstate and 65 EDD for downstate.

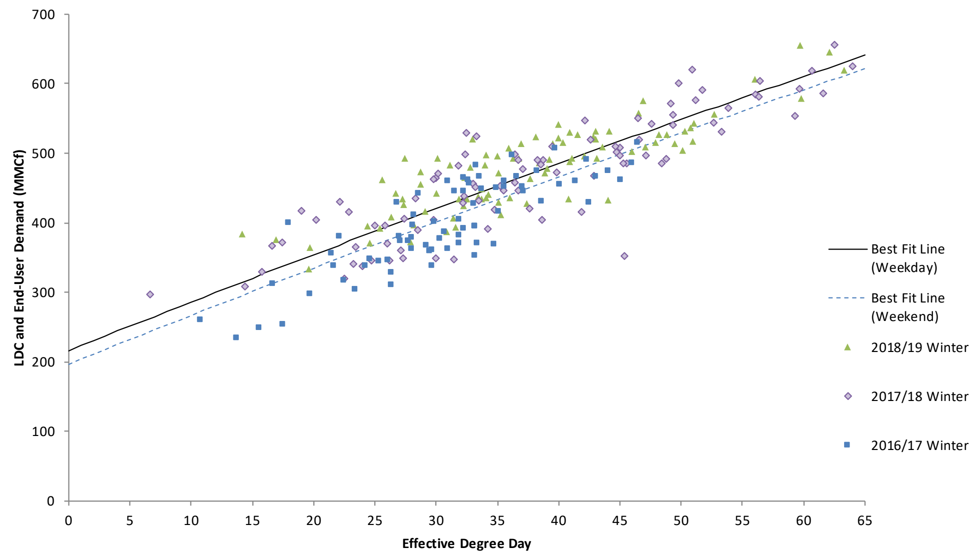
[30] Daily firm transportation to New England and state pipeline capacities are estimated based on data provided by EIA using their "U.S. State-to-State Capacity" dataset and discussions with NYISO staff. Combining these with our estimate of LDC retail gas demand determines the daily quantity of non-firm gas available for electricity generation. For additional detail, see Appendix B.5, EIA, Natural Gas Pipeline Data, "U.S. State-to-State Capacity," available at https://www.eia.gov/naturalgas/data.php.

[31] Data on LDC retail gas demand is from S&P Global Market Intelligence and represents deliveries to LDCs and end-users during the intraday 3 nomination cycle. Data on historical temperatures by NYISO zone was provided by NYISO.

[32] The upstate graph includes the following data: a simple average of historical temperatures in zones A through C and all gas delivery to LDC or delivery to end user points not located immediately next to a power plant in counties in zones A through C. The downstate graph includes the following data for Rockland and Westchester counties: a simple average of historical temperatures in zones H and I, and all gas delivery to LDC or delivery to end-user points not located immediately next to a power plant in Rockland and Westchester counties.

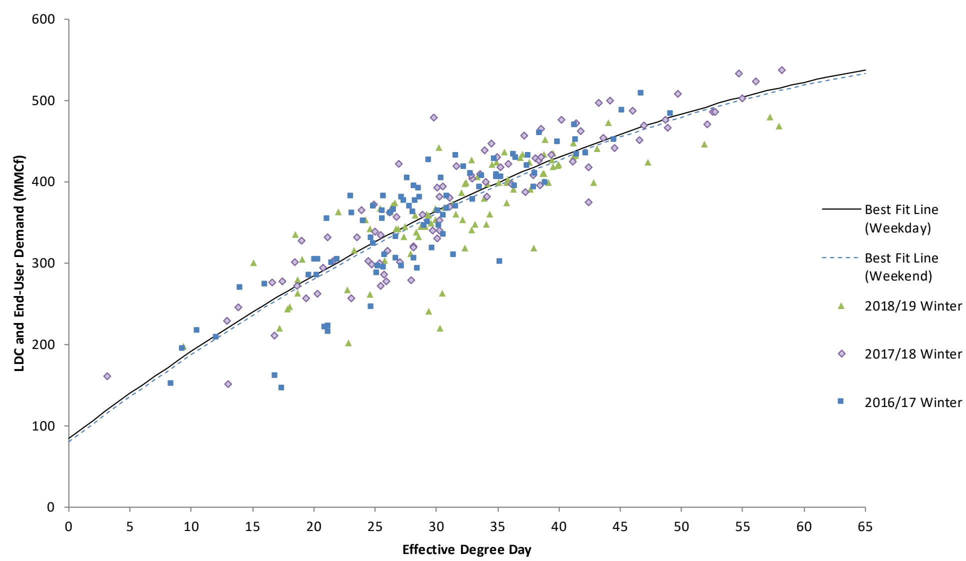
[33] "Design day" is the maximum daily retail gas demand estimated by each natural gas LDC at historically cold temperatures, and serves as the basis for LDC natural gas supply and transportation planning. Each LDC in New York State annually files a design day gas demand forecast and a supply plan to meet that demand with the NYS Department of Public Service. See for example, New York State Department of Public Service, Report on the New York State Electric & Gas Supply Readiness for 2018-2019 Winter, Case No. 18-M-0272, "New York State Electric & Gas and Rochester Gas and Electric 2018-2019 Winter Supply Plan," July 16, 2018, available at http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=18-M-0272&submit=Search.

Figure 7: Relationship between Degree Day and LDC/C&I Demand, Upstate



Notes:
[1] Total deliveries are the sum of scheduled capacity during the intraday 3 nomination cycle to LDCs and End Users. Chart includes all Zone A, B, and C gas points not located right next to a gas power plant.
[2] Winter is defined as December, January, and February. 16 outlier dates in winter 2016/17 were dropped due to missing data.
[3] Effective degree day is defined as 65 degrees - Dry Bulb Temperature, and is taken as the simple average of Zones A, B, and C temperature data.
Sources:
[A] LDC and End-User Demand: S&P Global Market Intelligence.
[B] Temperature: NYISO.

Figure 8: Relationship between Degree Day and LDC/C&I Demand, Downstate



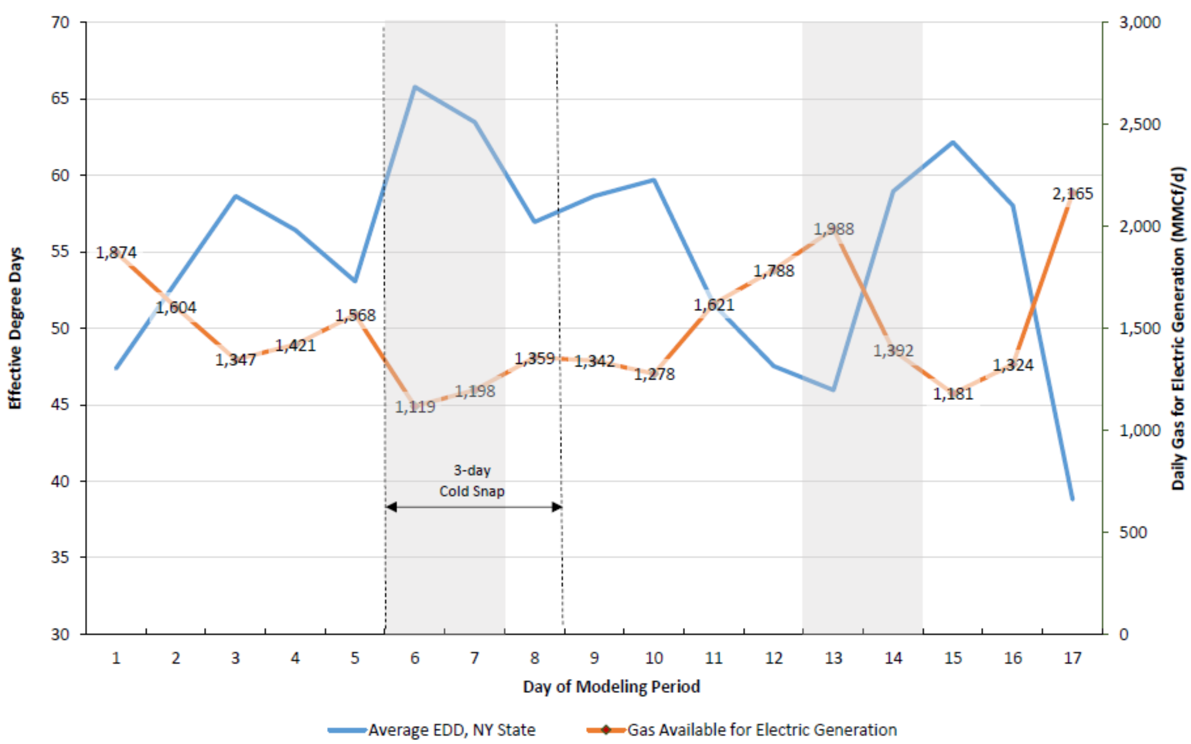
Notes:
[1] Total deliveries are the sum of scheduled capacity during the intraday 3 nomination cycle to LDCs and End Users. Chart includes all Westchester and Rockland county gas points not located right nextto a gas power plant.
[2] Winter is defined as December, January, and February.
[3] Effective degree day is defined as 65 degrees - Dry Bulb Temperature, and is taken as the simple average of Zone H and Zone I temperature data.
Sources:
[A] LDC and End-User Demand: S&P Global Market Intelligence.
[B] Temperature: NYISO.

Finally, the scaled LDC retail gas demand on each day of the modeling period is subtracted from the total natural gas pipeline capacity available in New York State (net of firm transportation through New York to external areas)[34] to determine the amount of remaining natural gas on a daily basis available to support electric generation. The daily gas available for electrical generation is spread equally across all 24 hours in a day to produce an hourly amount of gas available to electric generators based on each day's average temperature. As illustrated in Figure 9 below, the amount of natural gas available for electric generation is the total available pipeline capacity minus the firm LDC gas demand.

Figure 9: Diagram of Natural Gas Model

Figure 10 below shows how NYCA gas available for electric generation varies with daily EDD during the modeling period.

Figure 10: Gas Available for Electric Generation during 17-day Modeling Period



Notes:
[1] Weekends are shaded in gray.
[2] Effective degree day is defined as 65 degrees F - Temperature.

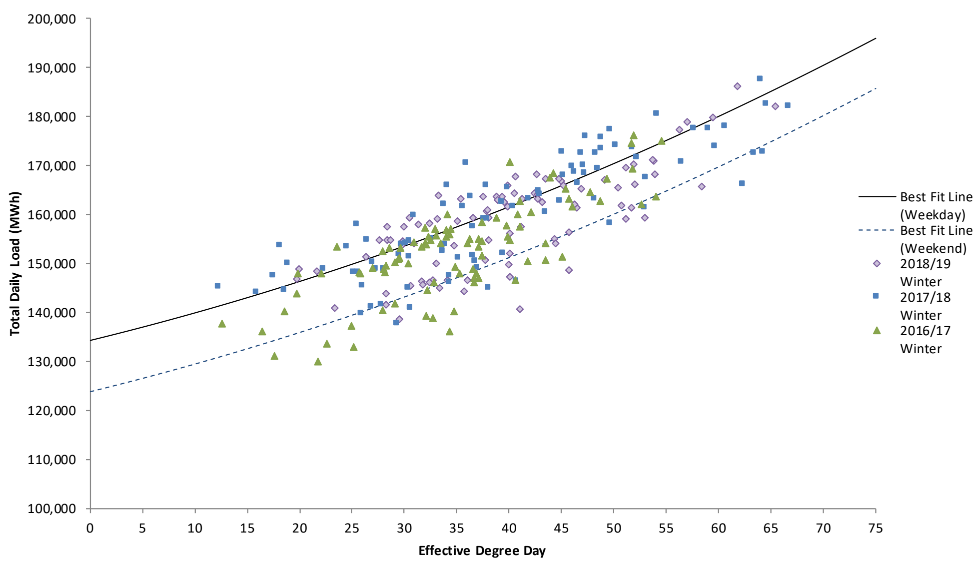
[34] See Appendix B.6 for detail on New York State's natural gas supply.

3. Relationship of Zonal Load and Weather

The next key factor in the analysis is the hourly demand for electricity under the modeled weather conditions. Hourly electricity demand during the extended severe cold weather event depends on the assumed temperature pattern, increasing during colder days and decreasing during mild days, but also observing a pronounced daily cycle. In order to specify hourly electricity demand during the modeling period, a forecast of load was established based on the historical relationship between NYISO load by zone and temperature.[35]

Data from three winters (2016/2017, 2017/2018, and 2018/2019) are used to estimate the statistical relationship between total daily energy and temperature for each modeled zone group/region (zones A-E, F, G-I, J, and K). Each modeled region showed a similar pattern of daily load that increased with increasing effective degree days, along with significantly lower loads on weekends (see Figure 11 below illustrating the electric load pattern for zones A-E).

Figure 11: Historical Winter Load and Best-Fit Line, Zones A-E 2016-2019



Notes:
[1] Winter is defined as December, January, and February.
[2] Effective degree day is defined as 65 degrees - Temperature.
Source:
[A] Load and Temperature: NYISO.

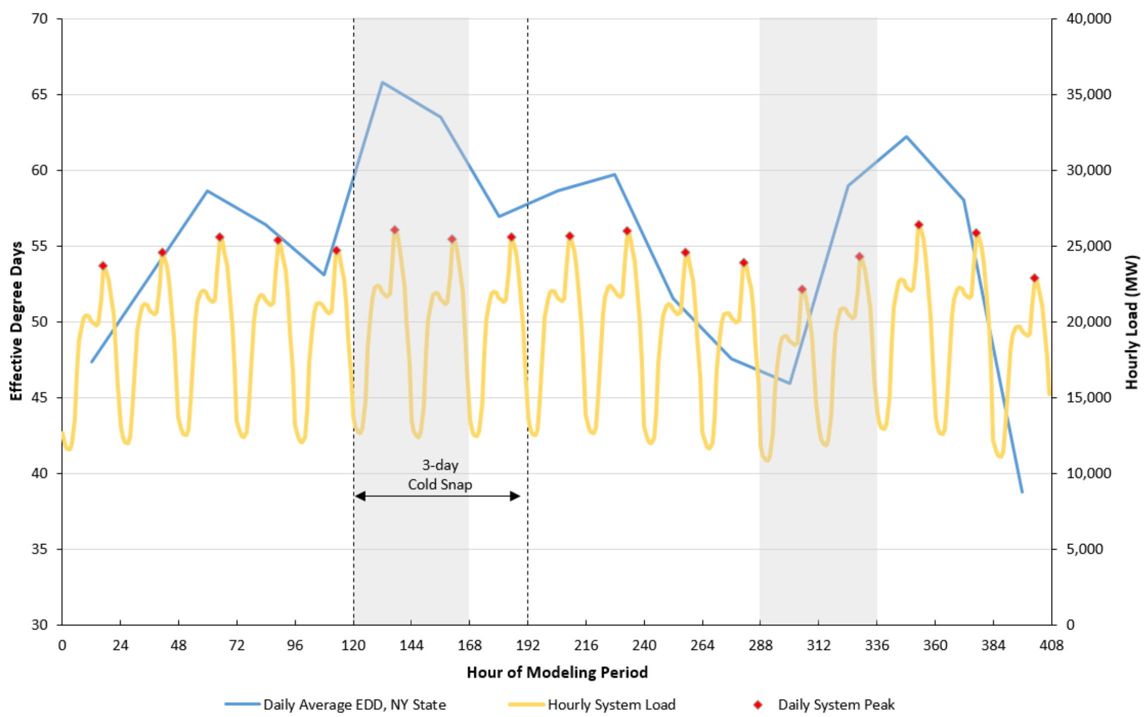
In order to construct a 17-day hourly load shape consistent with temperature and intraday load fluctuations, a single-day hourly load shape was scaled such that each day's modeled zonal total load matches the predicted zonal total load from the temperature/load forecast described above.[36] This single-day hourly load shape is based on the peak day of the 2023/2024 winter from the 2017 CARIS Phase 1 "System Resource Shift" (SRS) case (more detail on this daily load shape is provided in Appendix B.1). As a final step, winter peak loads were benchmarked to recent historical operational experience.[37] The final modeling period load shape is shown in Figure 12, with peak load in the modeling period at 26,458 MW (as compared to the historical winter maximum of 25,738 MW set in 2014).

[35] Data on historical loads and temperatures by NYISO zone was provided by NYISO.

[36] The load/temperature relationship for each zone is used to model that zone's predicted load.

[37] This benchmarking was accomplished through the application of a 7.5% reduction factor to loads across the modeling period hours.

Figure 12: Hourly Loads During 17-Day Modeling Period



Notes:
[1] Weekends are shaded in gray.
[2] Effective degree day is defined as 65 degrees F - Temperature.
Source:
[1] NYISO Weather and Load Data 1993-2018.

C. Common Inputs

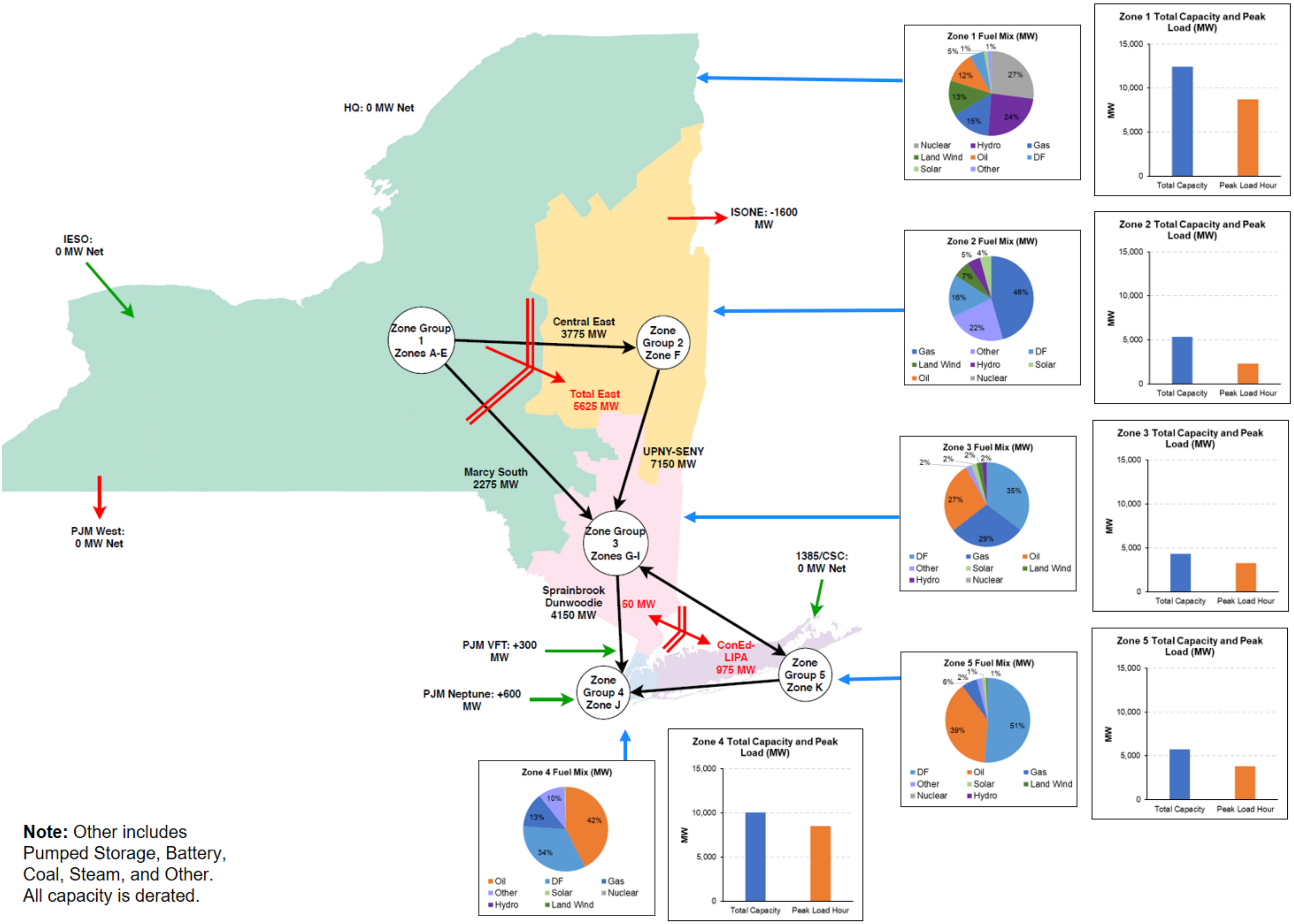
This section describes the sources of data underlying the analytic model. The model primarily uses the 2017 CARIS Phase 1 analysis as a starting point for load and generation assumptions. Specifically, the analysis uses the assumptions and certain outputs from the 2017 CARIS Phase 1 SRS case for the winter of 2023/2024. Figure 13 presents a summary of key generation capacity/fuel mix, modeling period peak demand, interregional transfers, and zonal transfer capability values that are built into the model.

1. Load

The underlying hourly load profiles for the winter 2023/2024 period used in the 2017 CARIS Phase 1 SRS case were a main input into the load modeling as described in Section III.B.3.[38]

[38] 2017 CARIS Phase 1 Report, pages. 24 and 36-38.

Figure 13: Energy and Fuel Security Model Input Summary



2. Existing Generation

The generation fleet used in our model is based on the units listed in-service in the 2017 CARIS Phase 1 study. The 2017 CARIS Phase 1 "Business-as-Usual" (BAU) case makes several assumptions related to unit specific retirements and additions,[39] and the 2017 CARIS Phase 1 SRS case adds several incremental changes to the NYISO's resource mix.[40] Both the 2017 CARIS Phase 1 BAU resource changes and the incremental 2017 CARIS Phase 1 SRS case modifications are discussed in detail in Appendix B.1. Notably, by the 2023/2024 winter period the 2017 CARIS Phase 1 SRS case assumes all coal resources in New York are retired as well as both Indian Point 2 and 3. Additionally, the 2017 CARIS Phase 1 SRS case assumes 8,475 MW (nameplate) of wind and solar resources are added to the system by the winter of 2023/2024.[41]

While fossil resources are dispatched according to the stacking order established in the model (as described in Section III.D.1), renewables are dispatched using hourly profiles. Wind and solar output comes directly from the 2017 CARIS Phase 1 SRS case. The underlying weather shape for the 2017 CARIS Phase 1 study is based on data from 2002.[42] As such, the coldest 17 -day period in the winter 2002 was identified, and the predicted renewable output from the 2017 CARIS Phase 1 SRS case during the 17 coldest days in the winter 2023/2024 was used as the wind and solar output in the model.[43]

The model assumes the addition of 350 MW of new battery storage capacity across NYCA in-service by the winter 2023/2024 period.[44] The model assumes that these new battery storage facilities run on a daily charge/discharge cycle where batteries discharge at capacity between 4 PM and 8 PM, and charge during the night between 1 AM and 5 AM, using a round-trip efficiency of 85%.

For other non-fossil fired resources (including hydro, pumped storage, and nuclear), the output profiles used are based on historic winter operations and average winter outages. For a detailed discussion see Appendix B.2.

3. Transmission Limits and Imports

In order to accurately model geographic constraints on electrical generation and transmission, a simulated and simplified version of the NYISO transmission network is used in the fuel security model. New York has a concentrated geographic distribution of load downstate, but generation capacity is limited downstate, so a large amount of power must flow over transmission lines from upstate to downstate. NYISO divides the state into 11 geographic load zones, labeled as zones A through K, which are interconnected through transmission. In order to reduce the number of transmission lines required to be modeled, the model simplifies the network to 5 regions: Region 1 represents zones A-E, Region 2 represents zone F, Region 3 represents zones G-I, Region 4 represents zone J, and Region 5 represents zone K. In determining hourly electrical flows, transmission transfer limits based on an N-1-1 contingency analysis, as provided by NYISO (see Figure 14), were used. In all cases, the Western New York and AC Transmission Public Policy Transmission Need upgrades are assumed to be in-service during the modeling period.

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39 2017 CARIS Phase 1 Report, page. 24.

40 2017 CARIS Phase 1 Report, pages. 38-39.

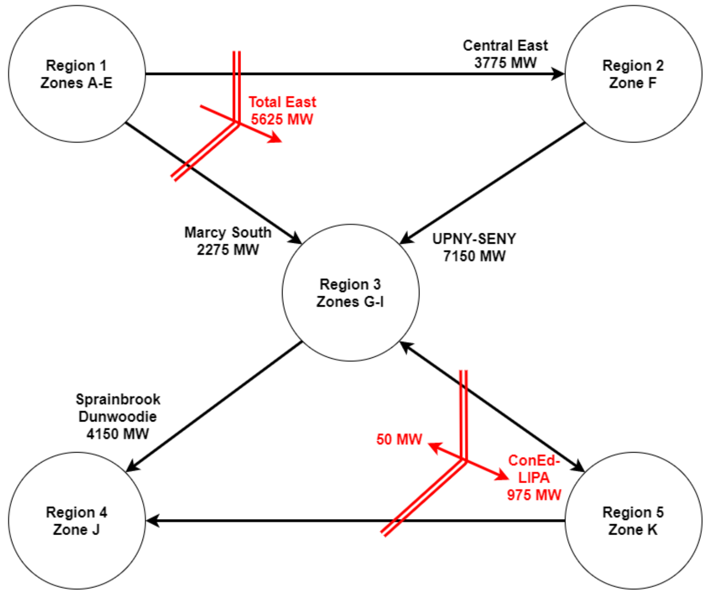
41 2017 CARIS Phase 1 Report, pages. 38-39.

42 2017 CARIS Phase 1 Report, Appendices B - J," April 2018, page. 4 (hereafter "2017 CARIS Report Appendices"), available at https://www.nyiso.com/documents/20142/2226108/2017-Report-CARIS2017-Appendix-B-J-FINAL.pdf/861e807c-9d9a-3d3b-43d1-43f8833f09e3.

43 The coldest period during the calendar year 2002 was identified using historic weather data from NYISO. The coldest period was between December 1-17, 2002, so the model uses predicted wind and solar output from December 1-17, 2024.

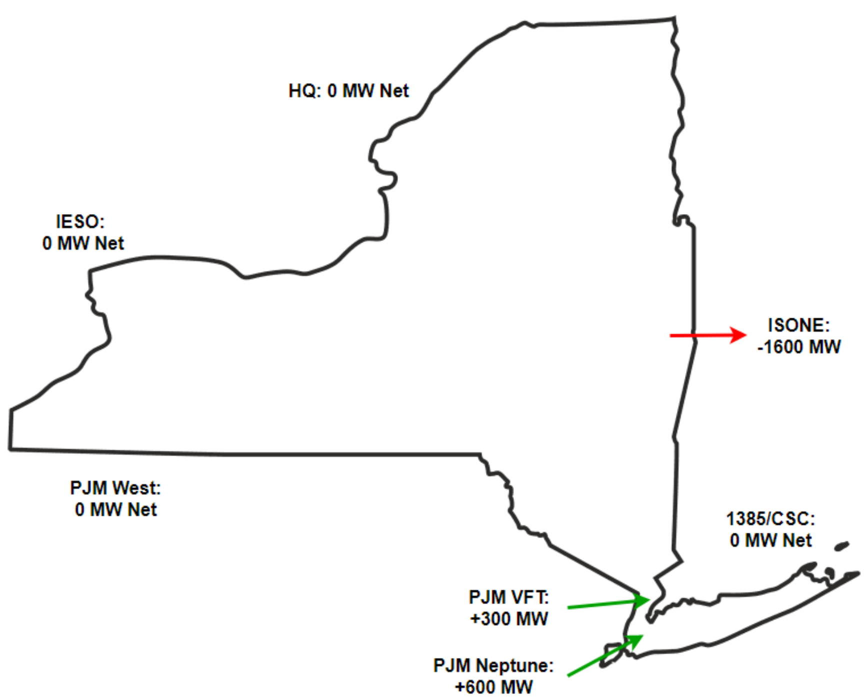
44 See State of New York Public Service Commission, Case 18-E-0130 - In the Matter of Energy Storage Deployment Program, Order Establishing Energy Storage Goal and Deployment Policy, Issued and Effective: December 13, 2018, p. 55.

Figure 14: Simplified Transmission Map and Limits



In addition to interzonal transfers, a fixed quantity of capacity imports and energy-only exports to neighboring regions were assumed during the modeling period. By default, 1,600 MW of energy-only exports to ISO-NE were assumed in each hour, and the level of capacity imports from PJM over the Linden VFT and Neptune transmission lines varied between either 900 MW or 0 MW depending on the scenario evaluated. The assumed flows for scenarios including 900 MW of capacity imports are represented in Figure 15.

Figure 15: Import and Exports During Modeling Period



4. Oil Replenishment

A central component to fuel security in New York is the ability of resources with inventoried energy to replenish their fuel stock. Given the winter 2023/2024 period resource mix assumed for the purposes of this study, fuel oil stored at oil only and dual fuel generating resources was the only fuel that required replenishment modeling. There were two assumptions required to model oil replenishment capability: starting level of oil inventory and refill rates (that is, the rate at which a resource can refill its stored oil). Both the starting inventory and refill rates were developed using historic data reported by generators to the NYISO, and is discussed further in Appendix B.2.

Staring inventory was developed based on the oil or dual fuel plants' storage size, refill type, and location. There are three ways oil is replenished in New York: barge, truck, and pipeline. Storage tanks that refill by truck tend to be smaller in size and start the winter with higher levels of storage than those that refill by barge. Zonally, resources downstate have historically started the winter with higher levels of storage. The average starting level as a share of max tank size was applied to each resource's tank to determine the starting level. It was assumed that a resource would not replenish above its starting storage level.

Historic observed refill rates or capabilities are based on the data provided by each resource to the NYISO. These rates were used to model resource refill level capabilities. A refill threshold was established for each resource. Once the storage level dropped below this threshold, the resources refilled at its stated capability until it either crossed the refill threshold or reached its starting inventory level.[45]

D. Representation of Electric System Operations Under Winter Conditions

1. Transfer and Dispatch Logic

In order to determine how the electric system operates under cold winter conditions during the 17-day modeling period, electrical transfers and generation across New York were modeled using the 5-region transmission framework discussed in Section III.C.3. The electric system model is designed to meet all load needs and reserve requirements using available resources given transmission and operational constraints.[46]

In each hour, the model first prioritizes meeting load in each region (see Section III.B.3 for a full description of construction of the load profile). Next, the model attempts to meet the nested zonal reserve requirements, shown in Table 3. For the purposes of the model, all fossil units are assumed to be capable of providing reserves.

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[45] In some cases replenishment assumptions were set based on NYISO information related to specific resources.

[46] Note, however, that the analysis is not a production cost model which takes prices into account for unit dispatch.

Table 3: Regional Reserve Requirements

Region	Reserve Requirement (MW)
NYCA	2,620
Total East (F-K)	1,200
SENY (G-K)	1,750
NYC (J)	1,000
LI (K)	540

Note:
[1] The reserve requirement for SENY reflects the assumed in-service AC Transmission Public Policy Transmission Need upgrade.
Source:
[1] NYISO Operations.

In the first step of the model, non-fossil generation is dispatched in each modeled region and then transferred throughout the state to maximize load served. Solar and land-based wind units are assumed to generate based on hourly profiles used in the 2017 CARIS Phase 1 SRS case (see Section III.C.2). Hydroelectric and nuclear units are assumed to generate at fixed capacity factors based on historical winter averages and do not respond to load.[47] Load within each region is assumed to be served by non-fossil generation in that region first, followed by a modeling of inter-region electric transfers to distribute regional generation surpluses across the state. In the next step of the model, fossil units are dispatched as needed to meet load and reserve requirements. Fossil units of different fuel types are run in the following order during the modeling period:

1. Natural Gas Only (to extent non-firm gas is available)
2. Dual Fuel using natural gas as fuel (to extent non-firm gas is available)
3. Dual Fuel using oil as fuel (to the extent oil inventory is available)
4. Oil Only (to the extent oil inventory is available)

Within each resource/fuel type, more efficient units are dispatched before less efficient units. The dispatch order ensures that all natural gas available to support electricity generation in a given hour is used up before any oil is used for generation in that hour. Modeled inter-region electrical transfers mean that when gas is available upstate, it can support load downstate. Hourly liquid fuel inventory is tracked at a plant level, and oil is refilled as described in Section III.C.4.

2. Possible NYISO Actions

After all deliverable generation is dispatched, two types of NYISO actions are modeled as undertaken in hours when reserves would be violated or load would otherwise be unserved. First, the model can reduce energy-only exports to ISO-NE in any hours with potential reserve deficiencies. For example, the default assumed level of energy-only exports to ISO-NE (1,600 MW) can be reduced down to 0 MW, thus preserving fuel for generation within NYISO. Second, if reserve deficiencies or load losses still exist after exports are reduced to 0 MW,

[47] The Niagara hydroelectric plant is assumed to output on a daily cycle, with greater output during the day (hours 9-20) and less output during the night.

SCRs/EDRP can be activated. The model assumes that SCRs/EDRP can provide up to 4 hours of load reduction capability per activation for a maximum of 5 days during the modeling period. The assumed SCR/EDRP capability by modeled region are listed in Table 4.

Table 4: Winter SCR and EDR Capacity

Region	SCR + EDRP Capacity (MW)
Zones A-E	381
Zone F	74
Zones G-I	75
Zone J	331
Zone K	32

Source:
[1] NYISO 2019 Gold Book.

IV. Cases Analyzed: Combinations of Scenarios and Physical Disruptions

In order to test the resilience of the electrical system to different possible system conditions during future cold weather events, a number of future cases were evaluated in the analysis. These cases are organized around two dimensions: First, a set of "scenarios," which are each a starting point for the electrical system during the modeling period. Second, these scenarios are assessed against a set of "physical disruptions," which are primarily intended to simulate possible short-term adverse events (evaluated singularly or in combination) that coincide with the modeling period.[48] The scenarios and physical disruptions are combined into a series of cases, the results of which were analyzed. The sections that follow summarize the scenarios and physical disruptions that make up the cases reviewed.

A. Scenarios: Variations in Electric System Conditions

Eight primary scenarios were developed to represent different configurations of four system conditions – (1) the timing for the build out of new renewables, (2) the level of assumed capacity imports from neighboring regions, (3) the potential impact generating unit retirements in response to the 2023 emissions limits set forth in the proposed "peaker rule," and (4) differences in the expected quantity of non-firm gas capacity available for power generation. These categories are summarized below, and Table 5 shows how they are configured for each of the eight primary scenarios.

[48] Several condition-specific cases were also evaluated to test the impact of certain issues raised in NYISO and stakeholder discussions. For example, the potential impact of adding offshore wind, connected into downstate New York was assessed. The results of these additional modeling runs are discussed in Section VI below.

Table 5: System Scenarios

Scenario Type	Infrastructure	Imports	Oil	Natural Gas
Description	**REN:** delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels	**IM900:** 900 MW Capacity Imports **IM0:** 0 MW Capacity Imports	**PK:** NYSDEC "Peaker Rule" retirements	**NGR:** Reduced non-firm gas availability to support ~2000 MW of gas gen. in Zones A-F, ~1000 MW of gas gen. in Zones G-I, and no non-firm gas generation in Zones J and K
Scenario 1		**IM900**		
Scenario 2		**IM900**	**PK**	
Scenario 3		**IM0**		
Scenario 4		**IM0**	**PK**	
Scenario 5		**IM900**	**PK**	**NGR**
Scenario 6	**REN**	**IM0**	**PK**	
Scenario 7		**IM0**	**PK**	**NGR**
Scenario 8	**REN**	**IM0**	**PK**	**NGR**

1. Renewable Resource Additions

Wind and solar generation are assumed to be built in the 2017 CARIS Phase 1 SRS case at a rapid pace which will greatly increase total renewable capacity in New York by the winter 2023/2024 period. However, there is no guarantee that the schedule of new renewable additions assumed by the 2017 CARIS Phase 1 SRS case will be fulfilled. In order to account for possible circumstances that could delay the build out of new renewable capacity, scenarios were modeled where the new renewables additions are delayed, such that solar and wind capacity are reduced to 38.5% and 48% of levels assumed by the 2017 CARIS Phase 1 SRS case.[49]

2. Capacity Imports from Neighboring Regions

In short-term periods of severe winter conditions in the NYISO region, similar conditions are likely to be affecting NYISO's neighboring regions concurrently. Additionally, uncertainty exists as to the level of capacity imports into New York that will be attained in future years. To account for these uncertainties, two possible levels of capacity

[49] Compared to today's system that contains approximately 2,000 MW of wind capacity (nameplate) and 1,500 MW of solar capacity (nameplate), the scenarios that modeled a delay in the near-term deployment of renewable resources assumed approximately 2,500 MW of wind capacity (nameplate) and 2,700 MW of solar capacity (nameplate) for the winter 2023/2024 period.

imports from PJM to the downstate region are modeled across various scenarios: 900 MW, which represents imports over the Linden VFT and Neptune lines into New York City and Long Island, and 0 MW.

3. Potential Impacts of the NYSDEC Proposed Peaker Rule

The NYSDEC has proposed a revision to existing NO_x emissions limits on combustion turbines to lower allowable emissions during the March-October ozone season.[50] This proposed "peaker rule" will restrict the runtime of a number of existing peaking units in New York (particularly downstate), and may lead to the retirement of some of these units. To measure the potential impacts of this proposal, several scenarios assume the retirement of approximately 1,350MW (derated capacity after consideration of winter-specific EFORd data) of peaking units in Zones G, J, and K by the winter 2023/2024. The assumed retirement levels account for the quantity of compensatory MW identified as needed to avoid reliability violations in Zones J and K in the "peaker scenario" conducted in connection with the NYISO's 2019-2028 Comprehensive Reliability Plan.[51]

4. Natural Gas Availability for Electric Generation

In addition to the modeling period restrictions on natural gas availability to electrical generators due to competing retail gas demand from LDCs, other factors may further restrict natural gas availability in the entire region. To investigate the impact such factors jointly, scenarios were modeled where the availability of non-firm gas to support electric generation is sufficient to accommodate approximately 2,000 MW of gas fired generation in zones A-F, approximately 1,000 MW of gas fired generation in zones G-I, and none in zones J and K. While these assumed generic restrictions on availability of non-firm gas are not attributed to any specific circumstances, this quantity of reduced gas availability is consistent with NYISO operational experience during historical severe cold weather events.

[50] New York State Department of Environmental Conservation, "Proposed Subpart 227-3, Ozone Seasons of Nitrogen (NO_x) Emission Limits for Simple Cycle and Regenerative Combustion Turbines," available at http://www.dec.ny.gov/regulations/116131.html.

[51] For the 2023 requirements of the proposed "peaker rule," the compensatory MW amounts identified as being needed to avoid reliability violations were 240 MW in zone J and 320 MW in zone K. See New York Independent System Operator, "2019-2028 Comprehensive Reliability Plan," July 16, 2019, p. 28, available at https://www.nyiso.com/documents/20142/2248481/2019-2028CRP-FinalReportJuly-2019.pdf/51b573b7-9edb-bbb9-8a87-742e9e7c3b7f?t=1564421089120.

B. Physical Disruptions: Episodic Interruptions of Fuel or Resources

In addition to the development of scenarios, a primary set of event-driven interruptions impacting system operations (one of which is no disruptions) were developed. These events are referred to as "physical disruptions." These primarily relate to unexpected capacity out of service, or interruptions in one form or another in the supply of natural gas or fuel oil. The physical disruptions analyzed are summarized below and presented in Table 6.

1. Loss of Unit Capacity

During the 17-day modeling period, NYISO could lose generating capacity due to unexpected physical breakages or transmission failures. The study assessed the location and severity of these generating capacity losses using three alternatives: 1) Loss of unspecified capacity by doubling each unit's historic EFORd, which leads to a decrease of 5,152 MW in generating capacity across NYCA, as compared to the initial starting point assumptions of 2,576 MW of unavailable capacity (this is referred to in Table 6 as the "High Outage" disruption); 2) Loss of ~1,000 MW of oil-fueled (or dual fuel) capacity in the zones G-I (this event is referred to as the "SENY Deactivation" disruption in Table 6); and 3) Loss of a major nuclear facility upstate representing the loss of Nine Mile 1 and 2 (referred to as the "Nuclear Outage" disruption in Table 6).

2. Oil Storage and Refill Restrictions

Oil stocks on hand are important to the ability of the system to compensate for losses in natural gas supplies. However, there are a number of possible contingencies that could cause unit refill rates to drop or prevent certain types of refill altogether. For example, during previous cold periods, the rivers around New York City have frozen solid, which made it impossible for oil units on the rivers to refuel by barge. The impact of oil disruptions was tested with four disruptive events: 1) Loss of barge refueling (referred to as the "No Barge Refill" disruption in Table 6); 2) Loss of truck refueling (this is referred to as the "No Truck Refill" disruption in Table 6); 3) Loss of any oil refueling across NYCA (referred to as the "No Oil Refill" disruption in Table 6); and 4) Low initial fuel inventory, which could represent a cold weather event that happens immediately following another cold period, such that units are not able to fully refill in between or future conditions in which units with oil-fired storage capability procure lower levels of initial inventory compared to recent, past experience (this event is referred to as the "Low Fuel Inventory" disruption in Table 6).

3. Restrictions on Natural Gas Availability for Electric Generation

In addition to the previously discussed modeling period restrictions on natural gas availability for certain scenarios, there are other possible short-term causes of natural gas restrictions. For example, there could be physical breakages of compressor stations or pipelines that could limit natural gas deliveries. In order to model such contingencies in general, certain disruptive events were developed to represent the potential unavailability for non-firm natural gas to support electric generation: (1) throughout the entire NYCA (referred to as the "Non-Firm Gas Unavailable NYCA" disruption in Table 6); and (2) limiting such unavailability to zones F-K (referred to in Table 6 as the "Non-Firm Gas Unavailable F-K" disruption).[52]

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[52] Physical Disruption 11, "Extreme Disruption," represents circumstances where multiple physical disruptions (zero gas availability, loss of SENY generation, and zero refill capability) occur simultaneously, to maximize the stress on the modeled NYISO electrical system.

Table 6: Physical Disruptions

#	Disruption Name	Description
1	**Starting Conditions**	No physical disruptions
2	**SENY Deactivation**	Loss of significant capability (1,000 MW) in SENY (specifically, zones G-I)
3	**High Outage**	Double unit forced outage rate compared to historical averages
4	**Nuclear Outage**	Loss of major nuclear facility upstate
5	**No Truck Oil Refill**	Unavailability of truck oil fuel delivery based on historical events such as snow storms
6	**No Barge Oil Refill**	Unavailability of barge oil fuel delivery based on historical events such as NYC rivers freezing
7	**No Oil Refill**	Unavailability of any oil fuel delivery due to severe fuel limitations affecting both barge and truck refueling
8	**Non-Firm Gas Unavailable F-K**	No gas-fired generation capability available in zones F-K
9	**Low Fuel Inventory**	Reduction of initial oil storage by unit and oil fill max tank quantity to half of historical averages
10	**Non-Firm Gas Unavailable NYCA**	No gas-fired generation capability available anywhere in NYCA
11	**Extreme Disruption**	Combination of no gas-fired generation capability available anywhere in NYCA, loss of significant capability in SENY, and unavailability of any oil refill capability

C. Combination of Scenarios and Physical Disruptions

Finally, to test the joint impact of system condition differences and short-term contingencies, all combinations of the primary scenarios and physical disruptions were modeled. These model runs are referred to as "cases." These cases run the gamut from mild to extreme stresses on the electrical system. The results of the analysis of these cases is presented in Section VI.

V. Output Metrics

A. Model Output

The energy and fuel security model is run for each case identified for analysis (as described in Section IV, each case is a combination of a scenario and physical disruption). The model proceeds through a stacking order/dispatch sequence based on the data inputs described above, including physical constraints on unit operations and the flow of power between locations within New York. Results are presented along several metrics indicating system reliability performance, including the identification of potential loss of load events. The results are assessed both individually for each case, and across all cases. In this section, the model output metrics and graphics are described, followed by the process used to distill case results into a set of reliability risk assessments.

For each model run, the energy and fuel security model estimates or tracks:

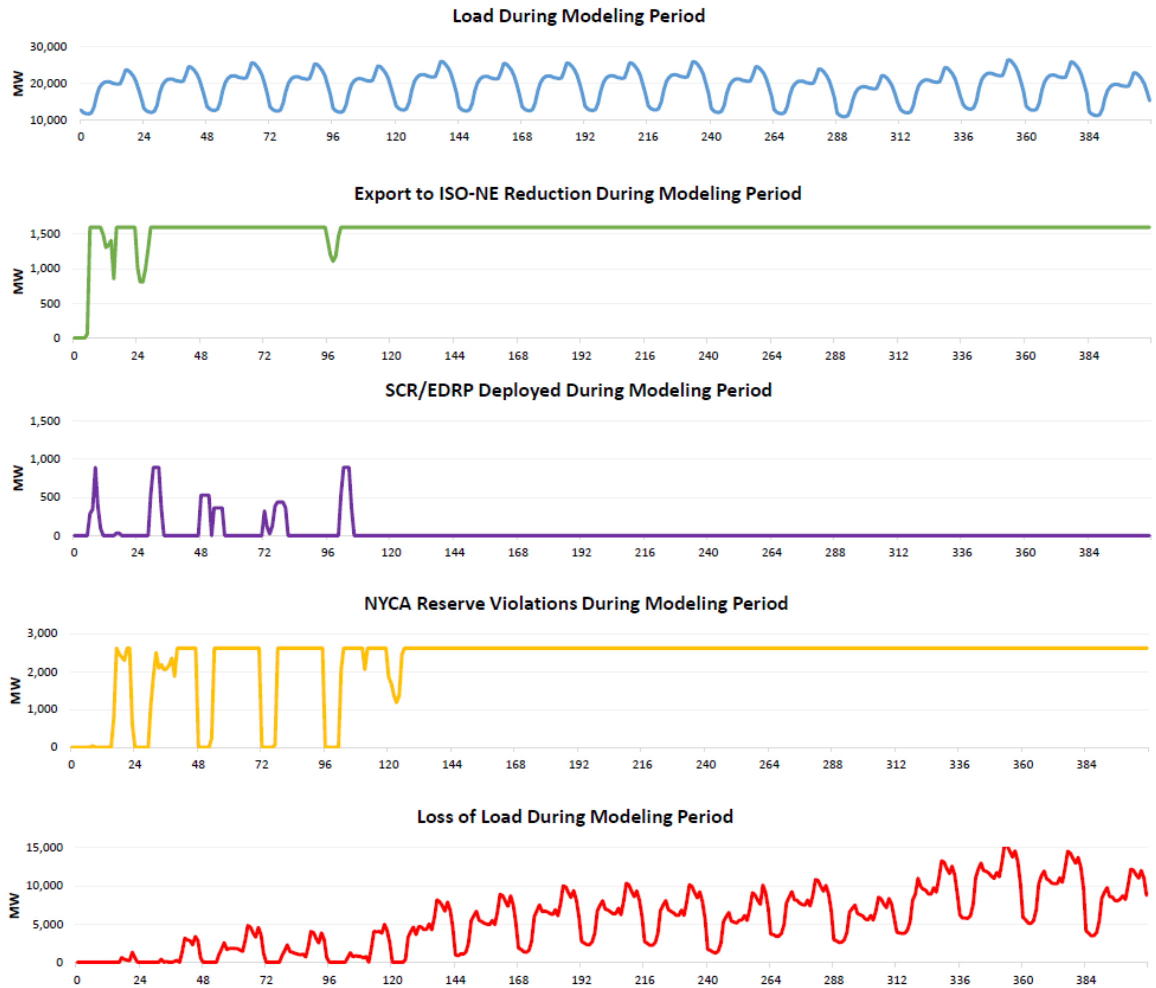
a. Natural gas demand and availability for power generation;
b. Hourly demand for electricity;
c. Hourly generation, fuel use, and stored fuel inventory by unit;
d. Fuel of operation for dual-fuel units;
e. Periodic oil inventory replenishment based on inventory levels, use, and refill capabilities;
f. Total hourly zonal generation relative to electrical demand (including reserves);
g. Hourly capacity imports, energy-only exports to New England, and transfers of power between zones;
h. Magnitude of actions taken to avoid the potential for a loss of load on an hourly basis, in each zone, including reduction in energy-only exports to New England, activation of SCRs/EDRP, and reserve shortages (reserve shortages are measured against the modeled reserve requirements – see Section III.D.1); and
i. Magnitude of potential loss of load on an hourly basis, in each zone, over the seventeen-day modeling period.

While the central focus of the model outputs are the magnitudes, duration and frequency of potential loss of load events, all of these metrics are considered. In order to assist in the detailed analysis of each case, and for comparison of potential LOL event drivers across cases, the model generates a consistent set of tables and graphics for each case. For illustration of the reporting outputs on case outcomes, Figure 16 through Figure 24 present an example of the full set of metrics generated in graphical and tabular form for one case - namely the most severe case run (scenario 8, physical disruption 11).

Figure 16: Example of Hourly Results Summary

Hourly Results Summary

Case Name: Scenario 8 - PD 11 Non-Firm Gas Unavailable (NYCA) + SENY Deact. + No Refill



Case Summary	
Load:	Revised Initial
Derate (EFORd) Increase:	Off
Renewables:	Delayed
Peaker Scenario:	On
Starting Storage:	Historical
Refill Contingency:	No Refill
Loss of Gas Fired Gen.	NYISO
Nuclear Contingency:	Off
Plant Outage:	Roseton
Import Scenario:	0 MW

Export Reductions	
Total Hrs.	403
Total MWh	636,961
Avg. MW	1,561.2

SCR Deployment	
Total Hrs.	34
Total MWh	15,436
Avg. MW	37.8

Reserve Violations			
Total Hrs.	371		
Total MWh	947,046		
Avg. MW	2,321.2		
First Hour with Viol.	8	First Hour, Zone K	41

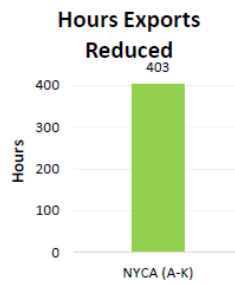
Loss of Load			
Total Hrs.	354		
Total MWh	2,188,073		
Avg. MW	5,362.9		
First Hour with Losses	17	First Hour, Zone K	65

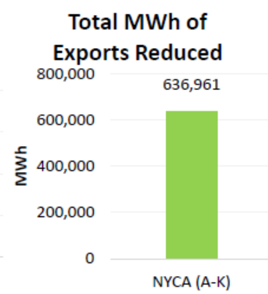
Figure 17: Example of Full Period Results Summary

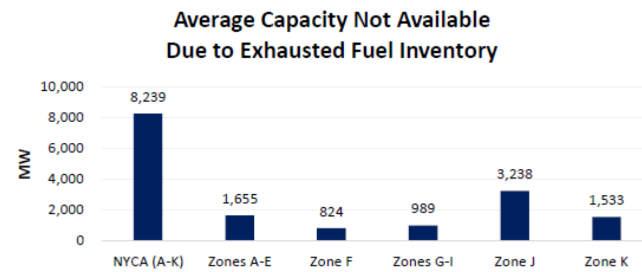
Full Period Results Summary

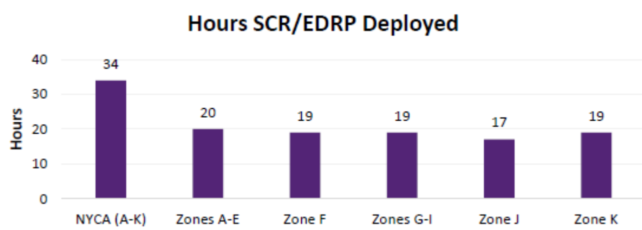
Case Name: Scenario 8 - PD 11 Non-Firm Gas Unavailable (NYCA) + SENY Deact. + No Refill

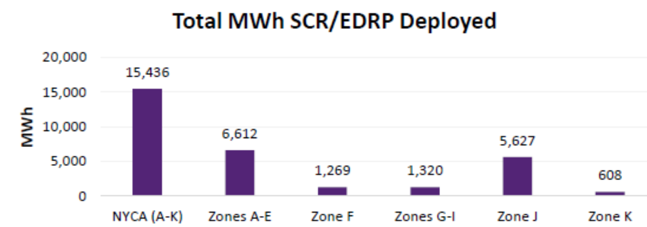
Case Summary	
Load:	Revised Initial
Derate (EFORd) Increase:	Off
Renewables:	Delayed
Peaker Scenario:	On
Starting Storage:	Historical
Refill Contingency:	No Refill
Loss of Gas Fired Gen.	NYISO
Nuclear Contingency:	Off
Plant Outage:	Roseton
Import Scenario:	0 MW

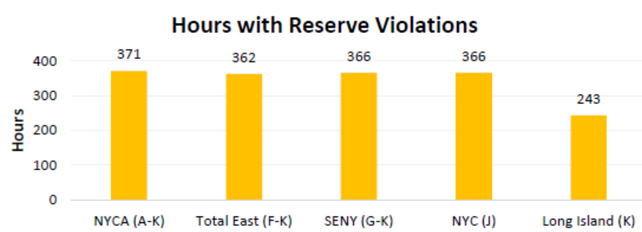


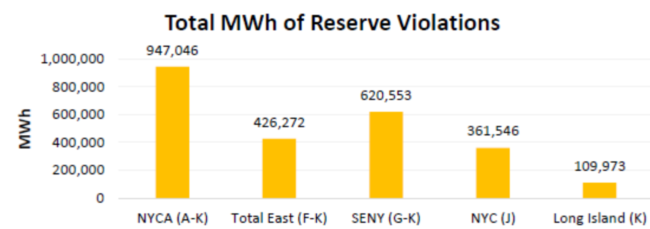


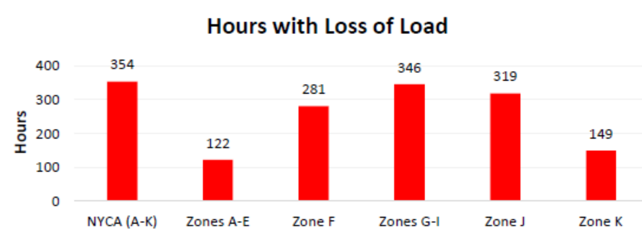












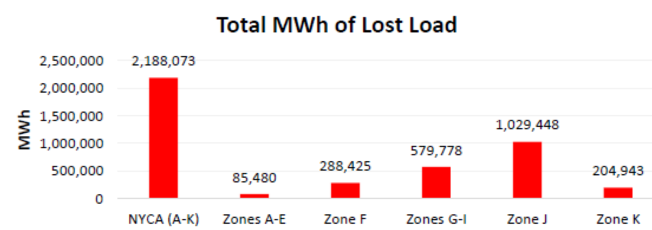


Figure 18: Example of NYCA Hourly Generation by Fuel Group

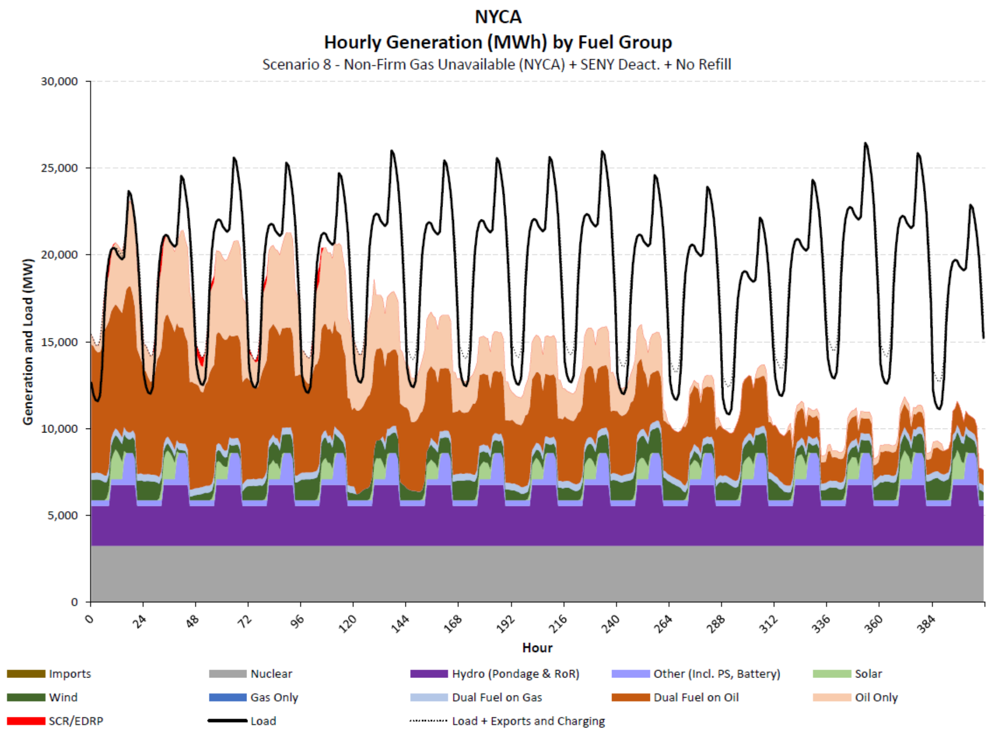


Figure 19: Example of Zone J Hourly Generation by Fuel Group

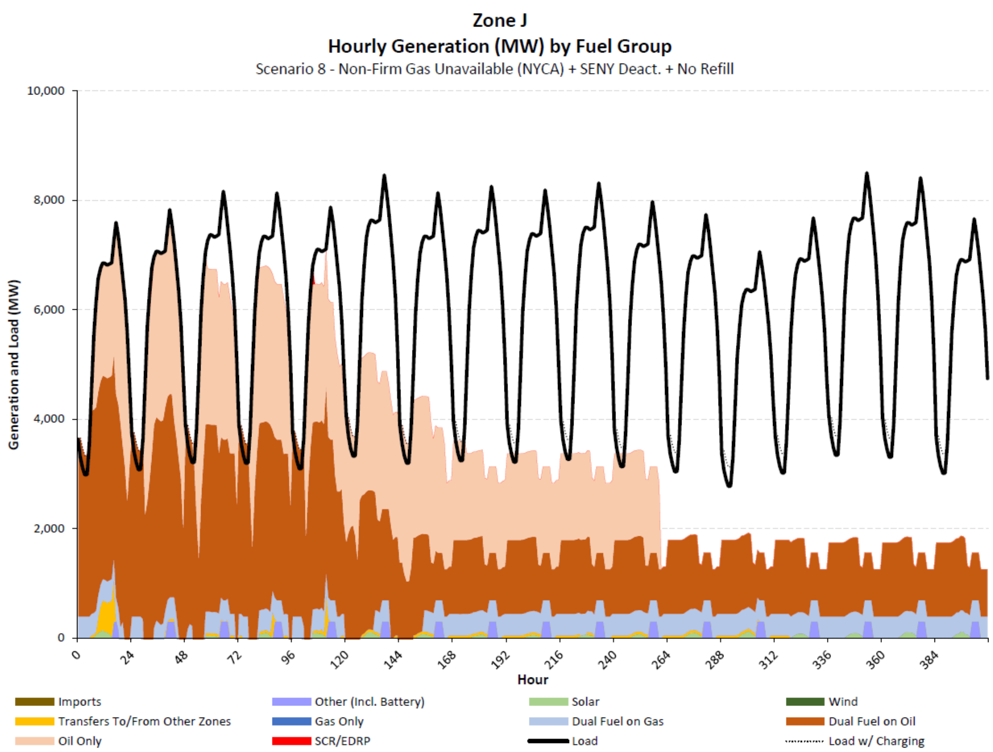


Figure 20: Example of Zone K Hourly Generation by Fuel Group

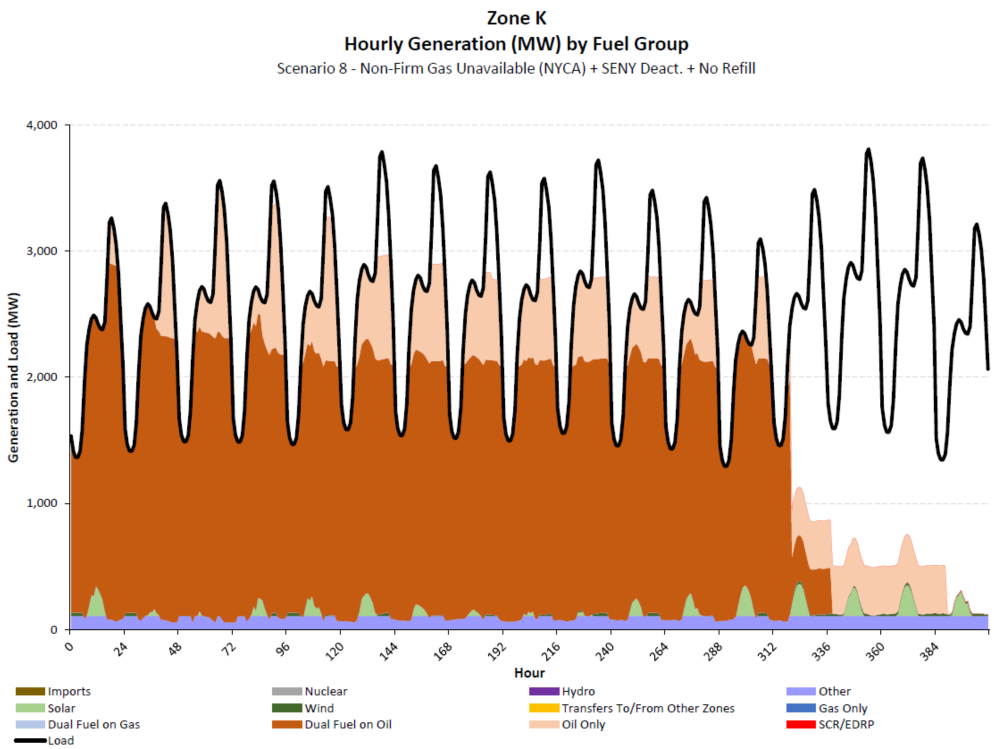


Figure 21: Example of NYCA Fuel Inventory

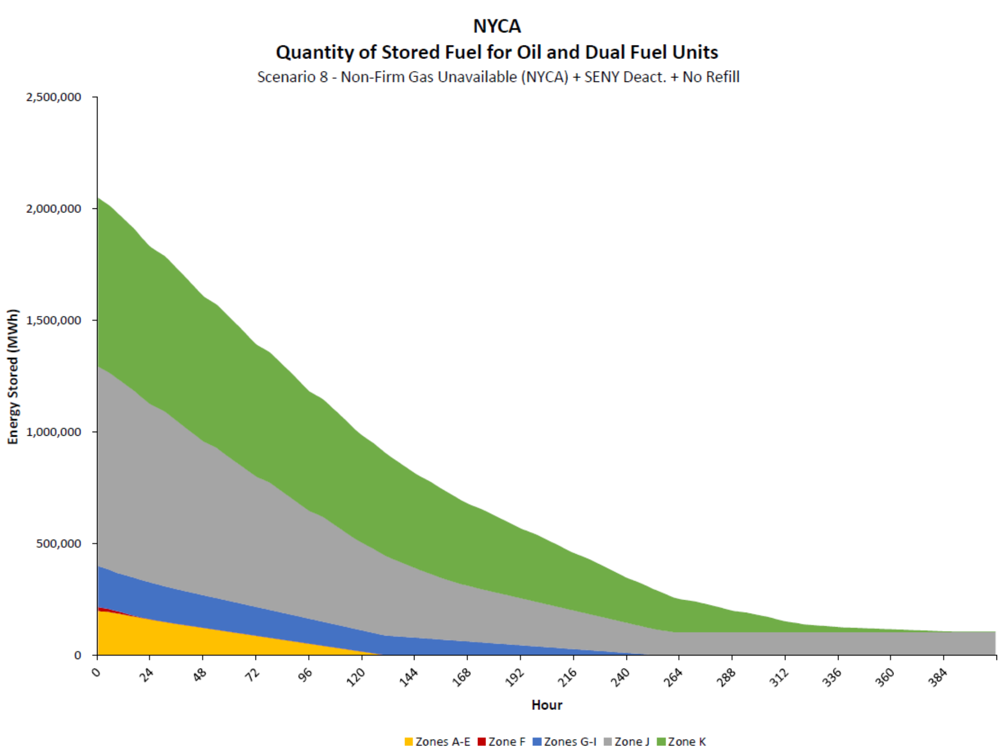
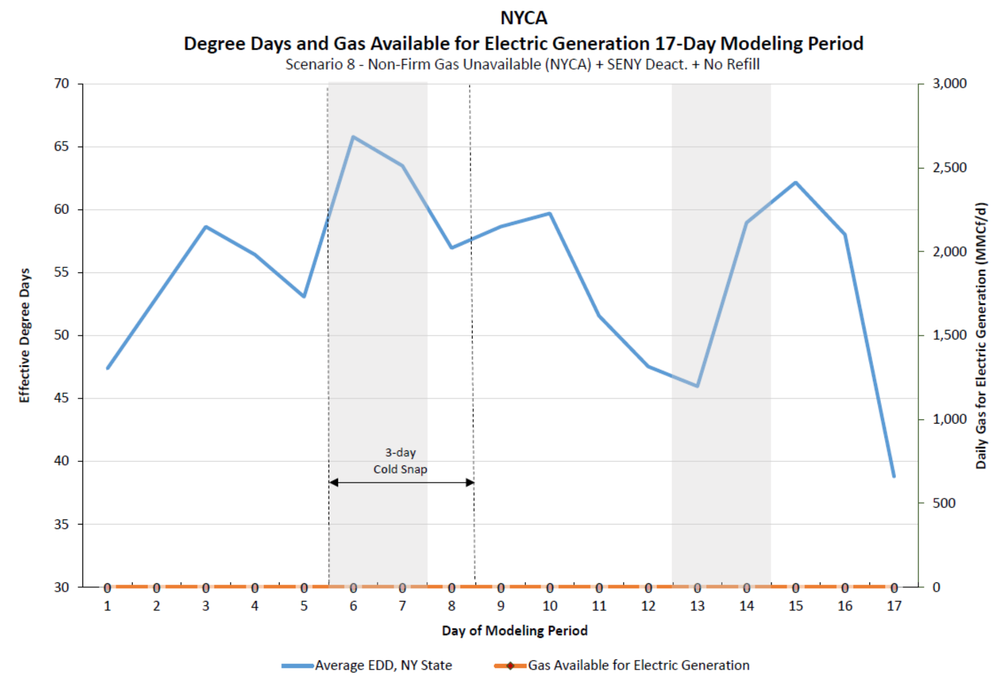


Figure 22: Example of NYCA Weather and Gas Available for Generation



Notes:
[1] Weekends are shaded in gray.
[2] Effective degree day is defined as 65 degrees F - Temperature.

Figure 23: Example of NYCA Emergency Actions and LOL Summary

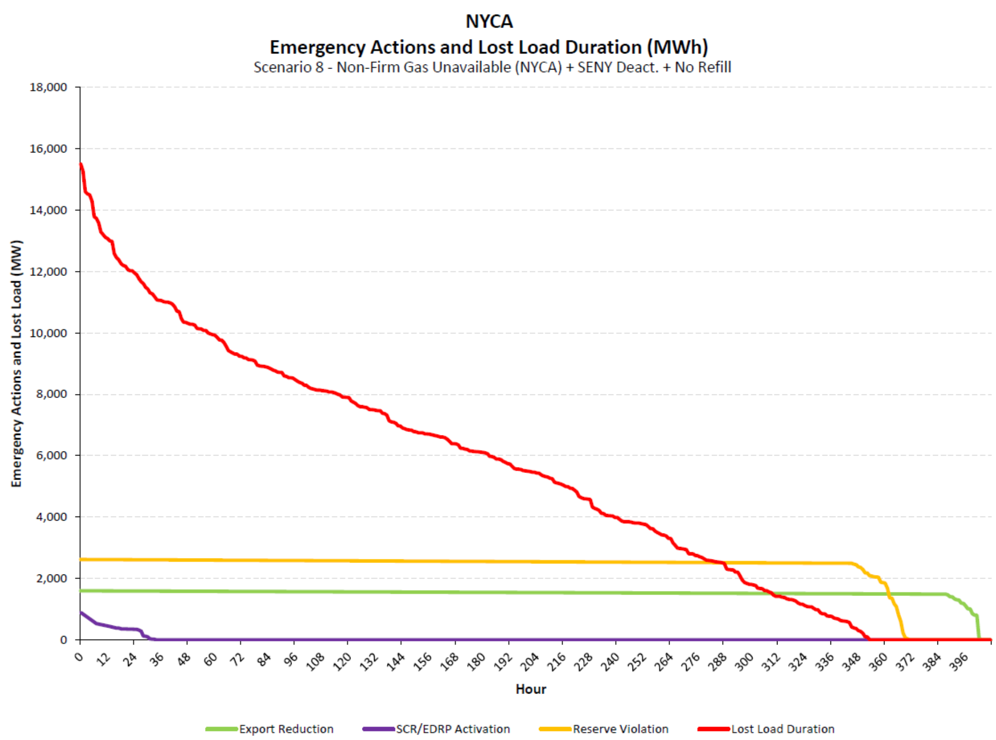
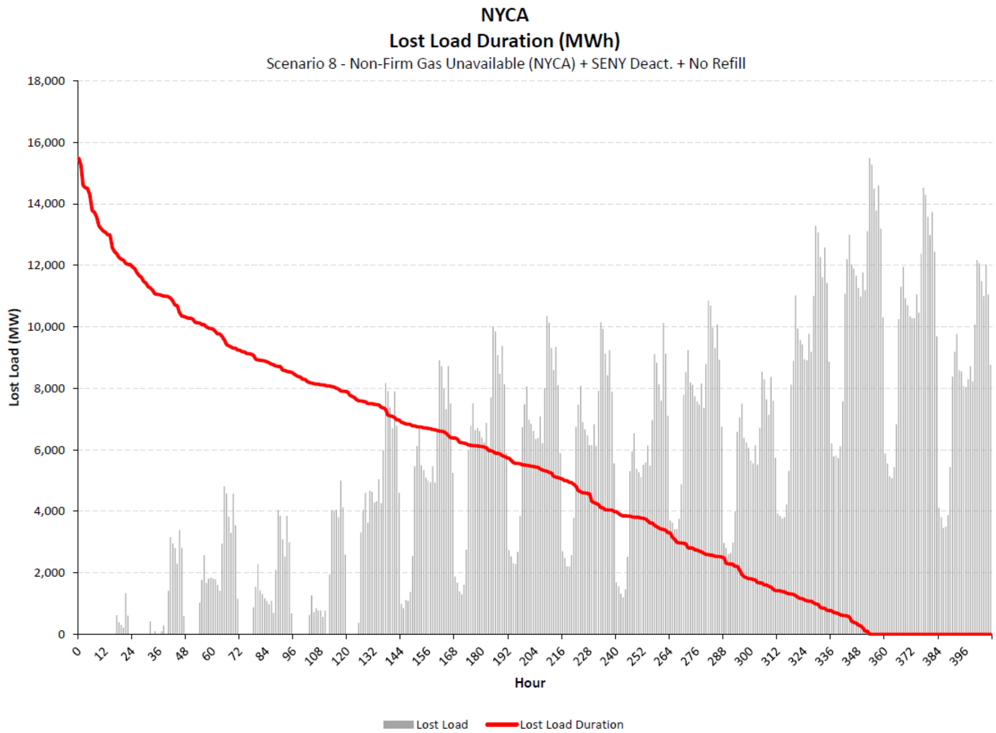


Figure 24: Example of NYCA Lost Load Duration



B. Analysis of Outcomes

The key focus of the analysis is on cases where there is potential LOL event, or where leading indicators (energy-only export reductions, SCR/EDRP activations, and/or reserve shortages) point to tight conditions and heighted reliability risks. Each case is reviewed and analyzed based on case conditions (generating resource availability, weather, unit additions/retirements) and the more dynamic factors that tend to most strongly influence system operations under cold weather conditions - including, for example, available natural gas (for power generation), initial fuel inventories, the drawing down of fuel inventories, and the ability and pace of inventory replenishment. Cases are analyzed based on number of hours with required NYISO actions (reduction of energy-only exports to New England and/or SCR/EDRP activations), hours with reserve violations after NYISO actions, and hours with potential load deficits after NYISO actions and reserve requirement violations. In addition, the severity of impact, meaning the magnitude, duration, and frequency of any identified reserve and/or potential load deficits, was also analyzed. In this first level of analysis, any case that leads to a potential LOL event of any magnitude or duration is flagged for further review.

However, the model itself does not take into account other emergency actions such as voltage reduction, public appeals, or targeted load shedding, nor does it automatically consider that there may be other steps that could be taken to resolve any transient or minor potential outage (e.g., allowing assets to move to emergency operation ratings). In addition, the model does not take into account the probability that the combination of scenario definition and the physical disruptions identified in a particular case will come to fruition. In other words, the model output metrics quantify the potential reliability *consequences* of each case - that is, the magnitude and duration of potential LOL events (or for leading indicators) under severe weather conditions and the postulated combinations of system scenarios and physical disruptions. Yet this is not a complete representation of the potential "risk" to the system.

"Risk" can be thought of as the product or combination of consequence and *probability*, or likelihood of occurrence. The probability of experiencing circumstances postulated for a given case can vary significantly. For example, some of the cases reviewed could involve system conditions that lead to severe potential LOL events, yet are highly unlikely to occur and, thus, represent diminishingly small operational risk. On the other hand, certain cases may be more plausible, yet represent consequences that are easily remedied (e.g., by the activation SCRs/EDRP) or otherwise do not present meaningful concerns or risk. Therefore, it is helpful when thinking about the implications of the analytic results to consider metrics of both probability and consequence.

Consequently, in addition to analysis of the model's output metrics, each case was categorized with respect to the degree of likelihood associated with the case conditions occurring. While this is necessarily a somewhat subjective exercise, the assessment is informed by the types of system conditions and circumstances generally used in operational studies. In other words, the system conditions presented by each case were assessed relative to the conditions imposed in other system operational analyses (e.g. a summer operational analysis that involves severe heat, the loss of generating capacity, and loss of a major transmission line).

Importantly, this analysis is not intended to replicate a probabilistic assessment of whether the conditions in question will or will not meet a standard such as loss of load no more frequent than once in ten years.[53] That type of assessment is not within the scope of this report. However, the relative likelihood of each case was qualitatively

[53] NYISO is obligated to plan for a system that has the "probability (or risk) of disconnecting any firm load due to resource deficiencies [], on average, not more than once in ten years." New York State Reliability Council, "Reliability Rules and Compliance Manual," February 9, 2018, page. 13, available at http://www.nysrc.org/pdf/Reliability%20Rules%20Manuals/RRC%20Manual%20V42_Final.pdf.

evaluated with an eye towards how the conditions might stack up against those imposed in other operational analyses. If conditions are far less likely than those typically considered, the case is given less weight. If similar or as likely, more weight is assigned to such a case.

The purpose of combining assessments of both probability and consequence in this way is to focus in on the subset of cases that (a) have the potential for significant reliability risks that may not be addressed, mitigated or eliminated through existing or easily-implemented actions, and (b) are probable enough to merit further attention and consideration of whether action is warranted. While this process necessarily involves the application of judgment and the use of assumed metrics of impact, the transparent nature of the analysis and comprehensive set of diagnostics allows entities to develop their own interpretation of results, to the extent they differ from those contained herein.

The analysis of cases is summarized in Section VI below, and Appendix D provides detailed exhibits that show the results - in the form of potential LOL duration curves - across all scenarios and all physical disruptions. “Heat maps” that cover results across all cases are also provided. In order to develop observations focused on which cases warrant further attention, the following categorization was developed based on the *combined* assessment of probability and consequence:

- **White:** The case leads to few or no potential LOL events, and none greater than 100 MW, and/or the probability of the combined scenario/physical disruption being realized is *extremely low, well outside* the types of system conditions and contingencies typically considered in operational assessments.
- **Yellow**: The case leads to potential LOL events greater than 100 MW but none greater than 1,500 MW, with such events generally of moderate duration or frequency, and the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Orange**: The case leads to potential LOL events greater than 1,500 MW, but the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Red**: The case leads to potential LOL events greater than 1,500 MW, and the probability of the combined scenario/physical disruption being realized is *on the order of* (or similar to) the types of system conditions and contingencies typically considered in operational assessments.

VI.Results and Observations

A. Overview

New York has witnessed significant changes over the last decade and a half, driven primarily by public policies and the emergence of natural gas as the fuel of choice for electricity generation. Going forward, the state is embarking on an ambitious and challenging period of transition - one that may require an unprecedented level and pace of change in power system infrastructure and operations to achieve the GHG reductions in all sectors of the economy required by the CLCPA. The increasing reliance on natural gas and weather-dependent renewables - and continued importance of oil-fired generation during winter months - do not *necessarily* increase the challenges associated with reliable system operations, and do not by definition increase the risks associated with maintaining system reliability. Nevertheless, in light of the current circumstances and context, NYISO asked Analysis Group to undertake a reliability assessment focused on fuel and energy security risks during winter operating conditions.

Analysis Group was tasked with assessing winter fuel and energy security risks and identifying key factors that will affect the likelihood and potential severity of any risks. The analysis was performed for the future winter of 2023/2024, with resource, fuel oil inventory, and demand assumptions based on recent data, documentation, and NYISO's operational experience. Publicly-available data was used (to the extent available) to assess the availability of natural gas for power generation (i.e., gas remaining after accounting for retail/end-user gas demand), and to evaluate potential impacts under severe winter conditions, akin to the worst experienced in recent decades.

The analysis represents an evaluation of potential reliability risks and impacts under *severe* winter conditions and *adverse* circumstances regarding system resources, physical disruptions, and fuel availability. Analysis Group's fuel and energy security model starts from a system under potential stressed system conditions, with variations on future system configurations - or scenarios and physical disruptions - modeled in a comprehensive set of cases. The focus of the analysis was thus intentionally designed to stress the system and test fuel security across a wide range of conditions. The objective is to better understand under what combinations of severe winter weather and highly adverse system conditions the reliability of the power system might be vulnerable, and what the potential impacts could be under such conditions.

Outputs of the various case runs were created to capture these conditions, and quantify them in terms of (a) magnitude of a potential load deficiency (in MW), (b) duration of deficiency (in hours or days), and (c) frequency of the occurrence of deficiencies over the course of the modeled cold weather period. Results for each case were synthesized in tabular and graphical forms to provide a comprehensive representation of the nature and magnitude of the fuel/energy security reliability risks (if any) under the range of system scenarios and physical disruptions analyzed.

These output metrics quantify the potential reliability *consequences* of each case - that is, the magnitude and duration of potential LOL events (or for leading indicators) under severe weather conditions and the postulated combinations of system scenarios and physical disruptions. An additional step of the review involved an evaluation of the *probability* (or likelihood) of case outcomes. This evaluation of probability was intended, in combination with the model's consequence analysis, to focus the review on a subset of cases that are both consequential and whose likelihood is at least on a par with system conditions and events that might typically be considered in system operational analyses.

The final step of the analysis involved careful review of case outcomes, with a particular focus on the subset of cases that - based on the reliability impacts of the case and the likelihood of realization - involved (a) potential conditions or system circumstances that could or should be evaluated in more detail, or (b) potential risks that warrant consideration of mitigating action.

B. Key Findings and Observations

1. The Changing Context for Fuel and Energy Security in New York State

With continued operation and availability of most of the assets currently expected to be in place in the winter of 2023/2024, the New York power grid is currently well equipped to maintain reliability in the winter, even under adverse winter system conditions. Only fairly severe and relatively low probability conditions or events tend create significant reliability risks.

Below is a summary of the assessment and key findings from the analysis based on existing resource expectations and conditions likely reflective of the winter 2023/2024 period. However, where relevant, findings related to longer-term expectations are also highlighted. For example, while not expressly modeled, in the context of fuel and energy security the biggest challenge for New York State, NYISO, and stakeholders over time will likely be in navigating the state's power system transition towards decarbonization in a way that does not jeopardize or compromise the resources, performance capability and infrastructure the analysis demonstrates are needed to support reliable winter operations.

The transition of the power grid - as evidenced by the requirements set forth in the CLCPA and other policies established by the state legislature and regulatory agencies in recent years - involves rapidly declining reliance on fossil fuels, and increasing reliance on weather-dependent renewables, energy storage, and other low-/no-carbon resources. Demand for electricity may substantially increase (and potentially change significantly in shape) over the next two decades, assuming electrification represents an efficient and least-cost path to decarbonization of transportation, building, and other sectors of New York's economy. Yet at the same time, the CLCPA requires that 70 percent of the state's electricity be provided by renewable generation by 2030, and 100 percent of the state's electricity be provided by zero-carbon generation by 2040.

The ongoing transition of the power system is an important consideration, particularly in light of the findings in this report. This review is focused on a "snapshot" of future system conditions in the winter of 2023/2024; yet at that time, changes in response to the CLCPA with the introduction of new resources and the changing economics of existing resources will only be just beginning to take hold. Putting the analysis into the context of the continued evolution of the power system beyond winter 2023/2024, one thing stands out: the availability and consistent contributions of adequate levels of natural gas-fired and oil-fired (or dual fuel) generating resources is necessary to maintain power system reliability in cold winter conditions in the near-term. This is particularly true for Long Island and New York City. Simply put, avoidance of potential loss of load events in these load centers, under plausible adverse winter conditions, requires operation of natural gas and oil-fired units. Reduction in the generation available from such resources - whether through capacity retirements, low initial oil inventories, reduction in natural gas availability for power generation, or interruptions in the ability to refuel oil tanks throughout the winter - represents the most challenging circumstances for reliable winter system operations in New York over the coming years.

Major increases in renewable generation and other clean energy resources (such as energy storage) into these zones - whether through offshore wind, additional transmission to accommodate incremental power flows from upstate renewables and other resources located outside these constrained regions, or both - can provide significant relief to and reduction in reliance on oil and natural gas in winter operations. The additional gigawatt-hours of generation from renewable resources - particularly offshore wind (injected into Long Island and New York

City) - can potentially help to meet some portion of peak demands, but perhaps more importantly can preserve oil and gas for continued operation over an extended cold weather event. Effective and durable energy storage capacity in these zones could also support operations during and around peak winter conditions. Yet the timing for the integration of these resources in the system and to what degree they may be relied on under severe winter conditions is not well known at this time. It will be critically important over the next one to two decades to fully understand and actively manage the impact of the evolving resource mix in New York.

2. Results

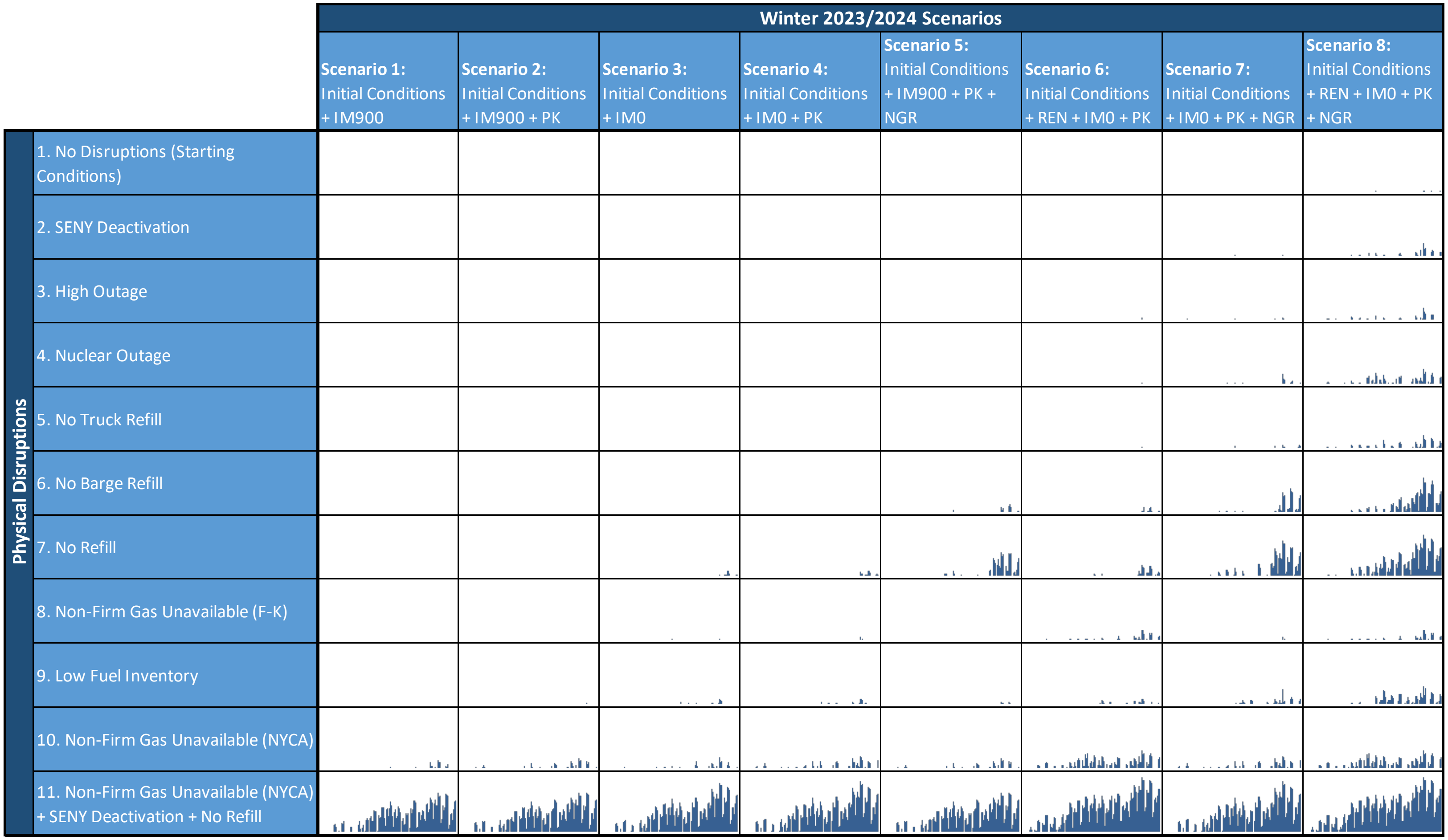
As described previously, the analysis begins with a supply and demand snapshot of the winter of 2023/2024, subject to historically severe winter conditions over the seventeen-day period. Over this period, the system is depicted through various combinations of system scenarios and physical disruptions, representing nearly one hundred cases in aggregate. Each case is run through the fuel and energy security model, which generates a detailed set of case diagnostics.[54] For each case the likelihood that the condition postulated would occur was also assessed.[55]

The key results for each case are depicted in Figure 25. Figure 25 represents the occurrence of potential LOL events across the seventeen-day period as a line chart within each case box, showing the relative magnitude, frequency, and duration of potential LOL events for each case. No line within the box indicates no potential LOL event associated with the case at issue. The most significant potential LOL events are seen for the most severe (and lowest probability) cases - namely, scenario 8 across all physical disruptions (the last column), and physical disruption 11 across all scenarios (the last row).

[54] The detailed results across all cases are further described in Section VI, with the detailed diagnostics for each case presented in Appendix E.

[55] See Section V.B and Appendix C for a detailed description of the method for assessing case probabilities.

Figure 25: Potential LOL Events by Case



Note: The scale of the axes are equal in all cells. The y-axis is set to have a maximum of 16,000 MW.

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

IM900 = 900 MW Capacity Imports.

IM0 = 0 MW Capacity Imports.

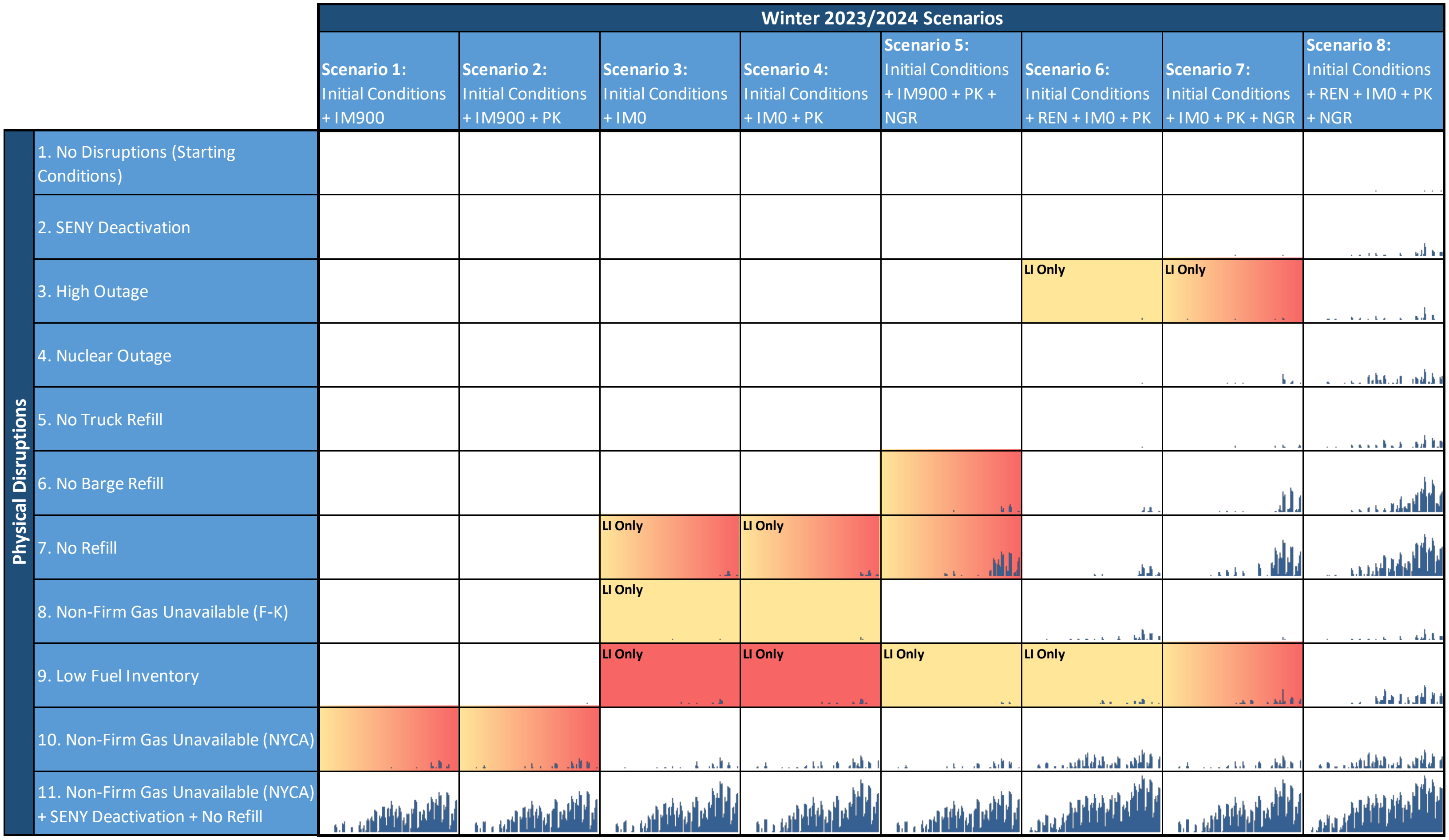
PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

While Figure 25 shows the potential for LOL events, it does not contain an assessment of the relative probability of each case being realized. In Figure 26, cases are color coded based on their level of risk, taking into account both the severity of potential LOL event impacts and an assessment of the likelihood of the conditions postulated in each case coming to fruition. The designation “LI Only” in a cell indicates that the identified, potential LOL events only occur on Long Island (zone K). With respect to the color coding, each case is categorized as follows:

- **Green:** The case leads to few or no potential LOL events, and none greater than 100 MW, and/or the probability of the combined scenario/physical disruption being realized is *extremely low, well outside* the types of system conditions and contingencies typically considered in operational assessments.
- **Yellow**: The case leads to potential LOL events greater than 100 MW but none greater than 1,500 MW with such events generally being of moderate duration or frequency, and the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Orange**: The case leads to potential LOL events greater than 1,500 MW, but the probability of the combined scenario/physical disruption being realized is *low, likely less probable* than the types of system conditions and contingencies typically considered in operational assessments.
- **Red**: The case leads to potential LOL events greater than 1,500 MW, and the probability of the combined scenario/physical disruption being realized is *on the order of* (or similar to) the types of system conditions and contingencies typically considered in operational assessments.

Figure 26: Heat Map of Reliability Risk



Note: The scale of the axes are equal in all cells. The y-axis is set to have a maximum of 16,000 MW.

Combined Assessment: Based on qualitative assessments of Probability, Consequence, and ease of Mitigation, grouped as follows:

- Consequence 0-100 MW or probability extremely low (far outside normal operational assessments)
- Consequence 100 - 1,500 MW, of moderate duration/frequency, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability on the order of normal operational assessments

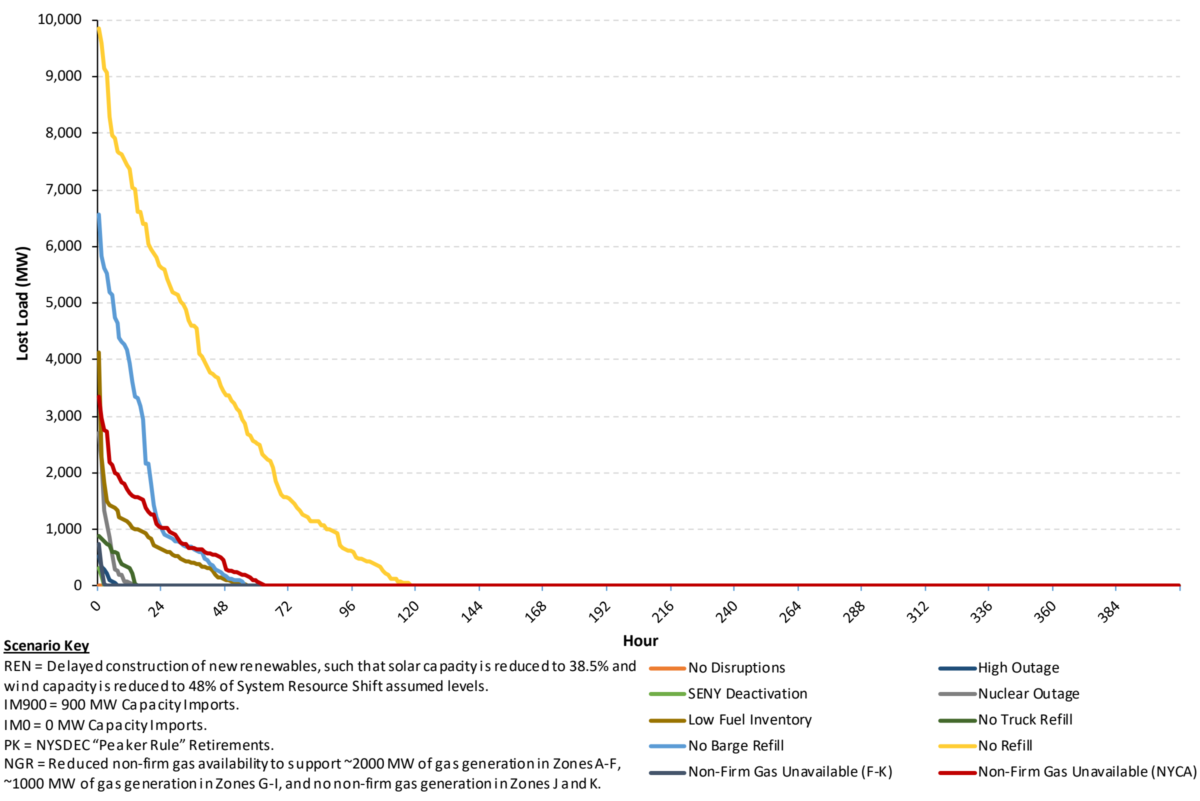
Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.
IM900 = 900 MW Capacity Imports.
IM0 = 0 MW Capacity Imports.
PK = NYSDEC "Peaker Rule" Retirements.
NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

The purpose of combining assessments of both probability and consequence in this way is to focus in on a subset of cases that (a) have the potential for significant reliability risks that may not otherwise be addressed, mitigated or eliminated through existing or easily-implemented actions, and (b) are probable enough to merit further attention and consideration of whether additional mitigating action is warranted (e.g., enhancements to operational procedures or market designs). While this process necessarily involves the application of professional judgment and the use of assumed metrics of impact, the transparent nature of the analysis and comprehensive set of diagnostics allows entities to develop their own interpretation of results, to the extent they differ from those contained herein.

It is useful to observe the results across physical disruptions for a given scenario, and *vice versa*. In this way it is possible to see the specific impact of a given set of system conditions or disruptive event on reliability risks, or to gauge the magnitude of impact from one case to another, all else equal. For example, scenario 7 contains a cross section of results that vary in location, probability, and impact across the physical disruptions. Figure 27 shows how both the severity of potential LOL events (in MW, the y-axis) and duration across the 17-day period (in hours, the x-axis) vary as the case steps from no disruptions through the various assumed physical disruption events.

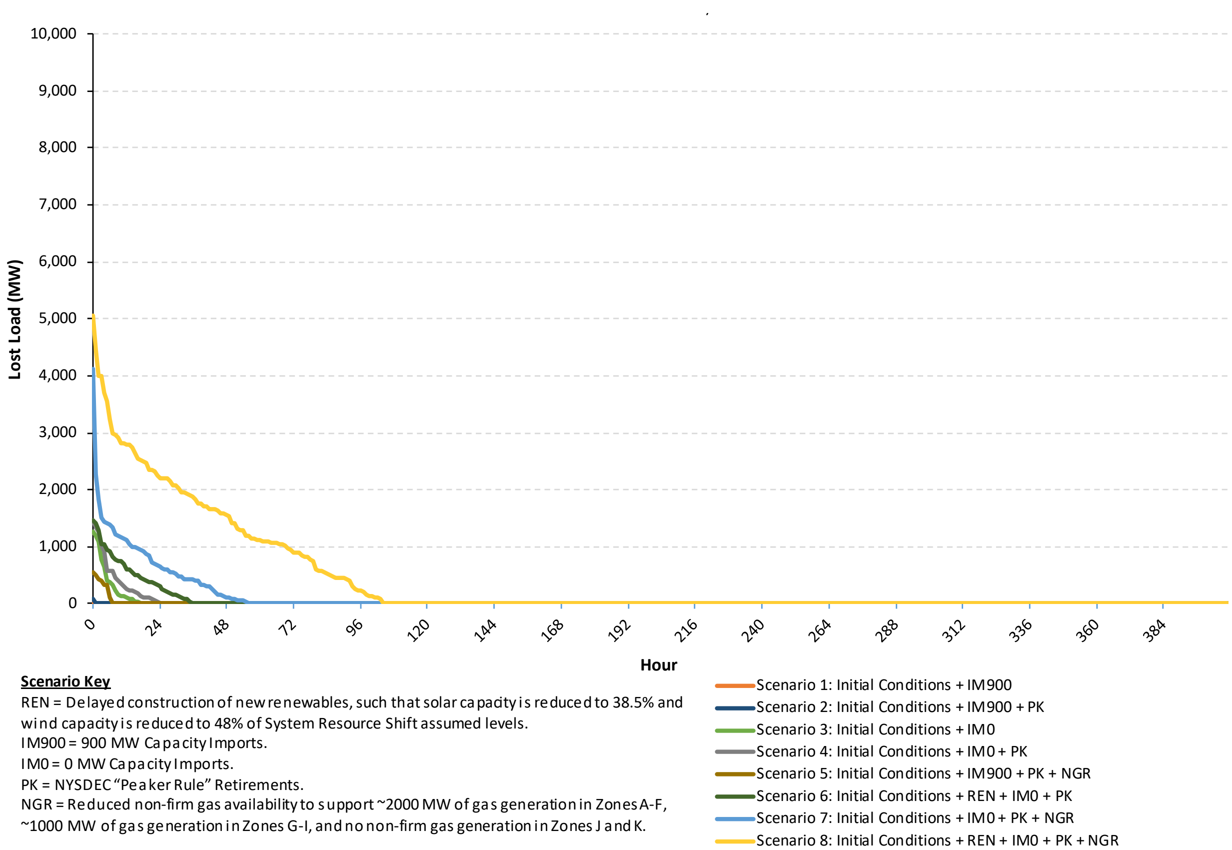
Figure 27: LOL Duration Curves for Scenario 7, All Physical Disruptions



Scenario Key
REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.
IM900 = 900 MW Capacity Imports.
IM0 = 0 MW Capacity Imports.
PK = NYSDEC "Peaker Rule" Retirements.
NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

Similarly, Figure 28 shows how potential LOL event severity and duration vary across scenarios for the single low initial fuel inventory physical disruption.

Figure 28: LOL Duration Curves for Low Initial Fuel Inventory Disruption, All Scenarios



Finally, LOL duration curves in Appendix D summarize the results across all cases by scenario and physical disruption, based on the analysis for the winter of 2023/2024.

3. Offshore Wind Sensitivities

In July 2019, NYSERDA announced the winners of the first offshore wind solicitation conducted in New York. The winning bids were submitted by Empire Wind, which plans to build an 816 MW wind farm south of Long Island, and Sunrise Wind, which plants to build an 880 MW wind farm east of Long Island, both with target in-service dates of 2024.[56]

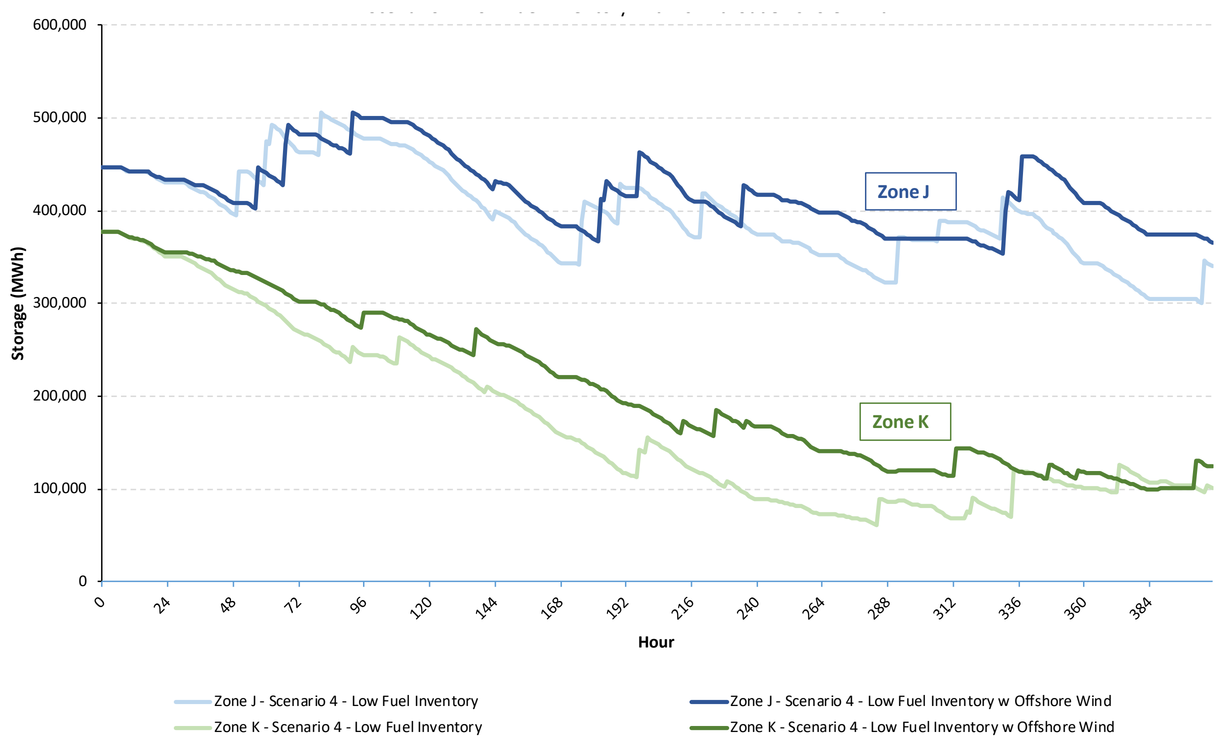
A significant level of the risks associated with winter operations identified in this study were associated with the downstate region, into which the new offshore wind facilities will interconnect. Consequently, while the procurements of offshore wind may not be in service until just after the winter 2023/2024 period, certain additional modeling runs were undertaken to assess the potential manner in which the new offshore wind projects may affect the potential LOL events that were otherwise identified downstate.[57]

The direct connection of this large quantity of energy directly into New York City and Long Island primarily helps preserve limited oil and natural gas for supporting reliable operations later in the modeled severe cold weather period. Figure 29 and Figure 30, show that in the downstate region, as the offshore wind generates energy over the winter modeling period it is in effect preserving fuel for use later in the period, avoiding the potential for LOL incidents due to a lack of fuel inventory (reducing the frequency and magnitude of potential LOL events). These new projects could also potentially contribute directly to meeting peak winter demands, but the extent of any such contribution is difficult to quantify with confidence given the variability and uncertainty in output coincident with winter peak hours and lack of historical operating experience for offshore wind in New York.

[56] NYSERDA, "Offshore Wind: 2018 Offshore Wind Solicitation Awards," July 2019, available at https://www.nyserda.ny.gov/-/media/Files/Programs/offshore-wind/Offshore-Wind-Solication-Fact-Sheet.pdf.

[57] For more details on offshore wind modeling assumptions, see Appendix B.7

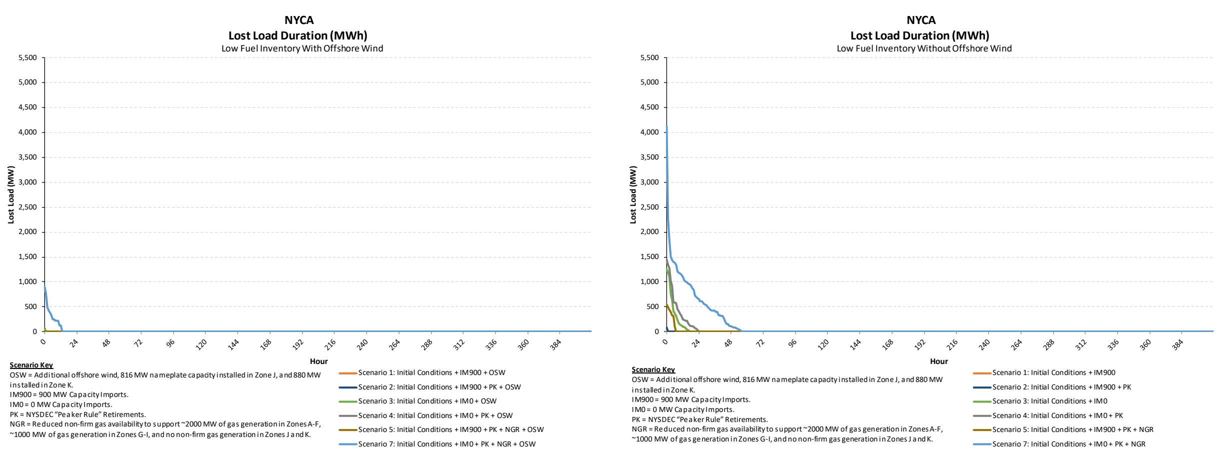
Figure 29: Oil Storage in Zones J and K with and without OSW, Low Fuel Inventory



Note

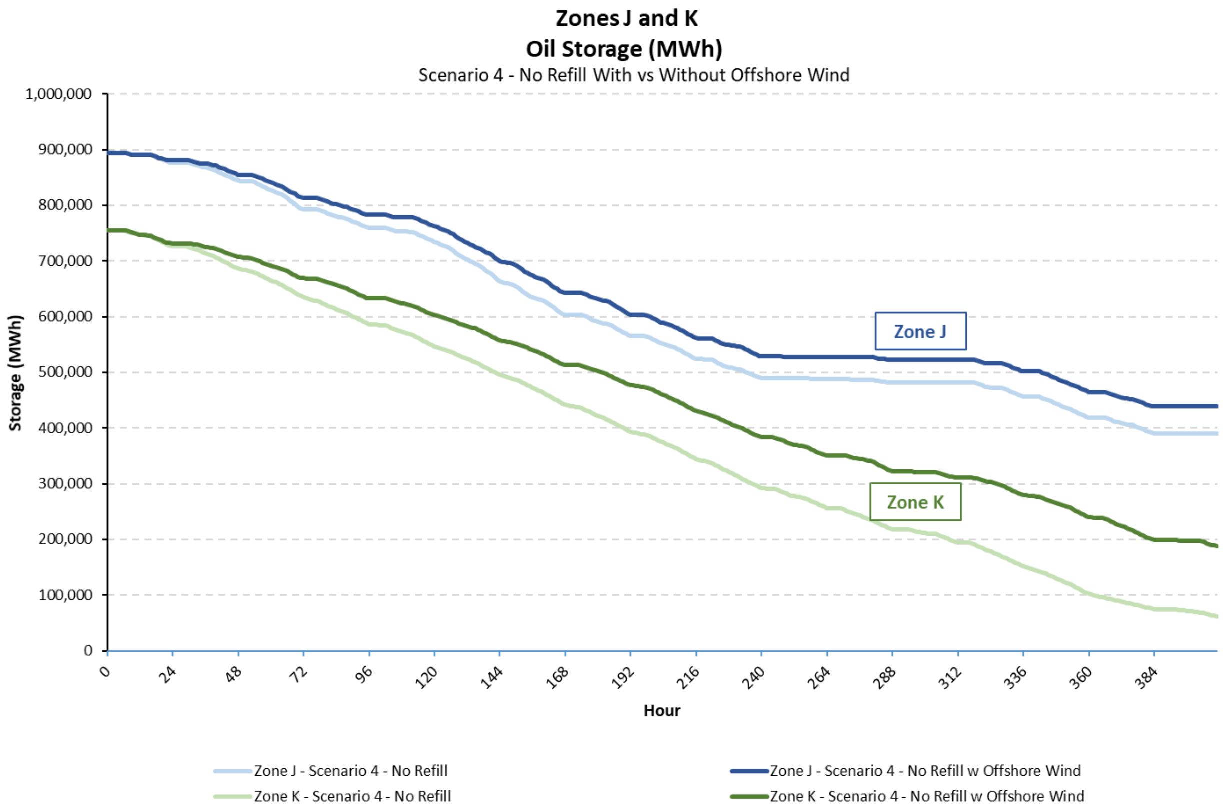
[1] Scenario 4 includes initial conditions plus 0 MW of capacity imports, plus NYSDEC "Peaker Rule" Retirements. The offshore wind cases include an additional 816 MW of nameplate offshore wind capacity installed in Zone J, and 880 MW installed in Zone K.

Figure 30: LOL Duration Curves Downstate with and without OSW



Offshore wind also mitigates potential LOL events when fuel replenishment is limited. Figure 31 further shows the impact of offshore wind on fuel inventories during the no-oil-refill disruption for scenario 4: oil is preserved for later in the modeling period, which helps reduce potential LOL events during the highest-load hours in Days 15-17.

Figure 31: Oil Storage in Zones J and K with and without OSW, No Refill



Note

[1] Scenario 4 includes initial conditions plus 0 MW of capacity imports, plus NYSDEC "Peaker Rule" Retirements. The offshore wind cases include an additional 816 MW of nameplate offshore wind capacity installed in Zone J, and 880 MW installed in Zone K.

4. Observations

Based upon the review of detailed case diagnostics, the following observations with respect to energy and fuel security in New York have been identified:

Based on the resources and operating capabilities assumed in the study, the New York power grid is well equipped to manage energy/fuel security risks. The overall risk associated with fuel and energy availability during winter months is relatively low. Across the cases reviewed that *do not* involve significantly adverse assumptions about future resource configurations or major disruptive events, power system reliability is not jeopardized. This is true even though the starting point for the analysis represents severe winter conditions. With the continued operation and availability of most of the assets currently expected to be in place in the winter of 2023/2024, the New York power grid contains sufficient diversity and depth of fuel supply to support reliable winter operations. This result is consistent with the historical operating experience in recent past winters, including during severe weather conditions.

NYISO has already taken many steps to address potential risks associated with fuel and energy security concerns. Part of the reason New York is well positioned is because many steps have already been taken to monitor, evaluate, and address potential risks associated with the availability of fuel and responsiveness of generating assets. This includes a variety of practices and requirements intended to ensure continuous monitoring of assets and fuel inventories, and visibility into the operations, capacities and constraints of interstate pipelines and local natural gas LDC systems; coordination of the timing of natural gas and electricity markets and the ability of generators to account for fuel opportunity costs in offers; the institution of requirements on downstate generators related to the capacity to operate on multiple fuels and switching fuels if and as needed based on prevailing temperature conditions; the incorporation of dual-fuel requirements for peaking plant technologies in the setting of the ICAP Demand Curves for downstate capacity regions (zones G-K); and the adjustment of reserve requirements statewide and downstate to reflect reserve needs in system operations. The set of steps already taken through changes in market rules and/or operating procedures have the effect of both increasing operator awareness of the risks and instituting requirements and financial incentives supporting the availability of fuel and the operation of assets important for reliable winter operations.

Significant potential LOL events appear in cases involving reduced operation of oil-fired generating assets, particularly in the downstate regions. New York encounters meaningful reliability challenges when initial inventories of oil are low, and/or the ability to replenish oil supplies is constrained by weather or other factors. In fact, the vast majority of potential LOL events occur in cases subject to physical disruptions associated with low initial fuel oil inventories at oil and dual fuel power plants, and/or reductions in or elimination of oil refill capability (truck, barge, and both). In these cases, potential LOL events tend to arise later in the seventeen-day modeling period as inventories are used up and not replenished.

Significant interruptions or reductions in the availability of natural gas for power generation can introduce challenges for reliable operations. Disruptions involving the loss of non-firm natural gas for power generation NYCA wide, or (to a lesser extent) only in zones F-K, lead to potential LOL events under most scenarios. The loss of non-firm gas across the state introduces significant potential LOL events in all scenarios; the loss of non-firm gas (for power generation) limited to zones F-K does not by itself cause potential LOL events unless other system limitations arise (i.e., import reductions alongside the potential retirement of units in response to the proposed "peaker rule," reduced oil refill capability, or delayed deployment of new renewable resources).

Dual fuel capability - with oil as a backup fuel to natural gas - is vital for maintaining reliability. Taking into consideration the demand for natural gas by LDCs for serving retail needs, there simply is not enough gas available for power generation downstate under prolonged, severe cold winter conditions to ensure reliable operations, absent the ability of dual-fuel units to switch fuels. While these resources may operate economically - and to the advantage of electricity consumers - most of the year on available non-firm supplies of natural gas, under severe cold weather conditions LDC demand and other firm natural gas transportation commitments (including for deliveries to neighboring regions) reduce available natural gas for power generation to levels below that needed for reliable system operations, absent the ability to switch to oil. Maintaining adequate dual fuel and other oil-fired operating capability is critical to reliable operations during averse winter conditions, especially in the downstate region.

A majority of circumstances leading to potential LOL events are constrained to Long Island. All cases with potential LOL events greater than 1,500 MW and probability of occurrence conceptually similar to normal operational assessments occur on Long Island only. Moreover, of the fifteen potential LOL events exceeding 100 MW across all cases, nine occur on Long Island only. Long Island's vulnerability stems primarily from the combination of limited import and internal transfer capability and a particular reliance on oil-fired capacity. Maintaining adequate imports and dual fuel (and other oil-fired) operating capability are critically important to reliable winter operations on Long Island.

Meeting the state's renewable and clean energy resource goals can provide valuable reliability support, and this may be particularly true with respect to offshore wind. The results demonstrate that delayed realization of renewable resource additions (as compared to the 2017 CARIS Phase 1, System Resource Shift case levels that are assumed under initial conditions) can lead to potential LOL events that would not otherwise occur when combined with other adverse system conditions. Moreover, additional analysis was undertaken to assess the specific impacts of adding the approximately 1,700 MW of offshore wind recently announced by the State as having been selected as winners of the first offshore wind solicitation conducted by NYSERDA (with roughly half injected into Long Island and half injected into New York City), since these new projects may be in service not long after the winter of 2023/2024. These additions made meaningful contributions to reducing potential LOL events in the downstate region, and particularly on Long Island. The connection of this large quantity of energy directly into New York City and Long Island primarily helps preserve limited oil and natural gas for supporting reliable operations later in the modeled severe cold weather period.[58] Similarly, a review of certain cases with limited magnitude and duration of potential LOL events could be eliminated through the operation of additional energy storage capacity in targeted locations.[59]

Over the longer term, the potential magnitude and pace of change to the resource fleet stemming from requirements under the CLCPA may be of far greater importance for evaluation than the considerations, scenarios and physical disruptions evaluated in this fuel and energy security study with respect to winter operational risks. The fundamental changes envisioned by the CLCPA suggest that the power system will play a critical role in decarbonization of the state's economy, with at least two fundamental shifts that will affect fuel and energy security during winter months. The first involves the potential electrification of transportation, heating and other sectors which may be needed to achieve the required GHG reductions in those sectors at the lowest possible cost to consumers. This could significantly expand and change the demand for electricity within New York State, and in particular in the downstate load centers that are most susceptible to winter energy security risks. The second is the *contemporaneous* decarbonization of the electric sector itself - requiring that 70 percent of all

[58] Our modeling of these scenarios uses generic NREL offshore wind generation output profiles for the offshore project areas, but are not based on any actual operating experience to date. See details in Appendix B.7.

[59] As described in Section III, the model assumes 350 MW of new energy storage resources in the winter of 2023/2024.

electricity be met through renewable generation *within roughly ten years* (by 2030), and that all electricity be provided by zero carbon resources within approximately twenty years (by 2040).

The potential for rapidly expanding demand for electricity combined with dramatic reductions in fossil-fired generation - including presumably the oil- and gas-fired generation that is currently critical for winter system reliability in the downstate region - warrants careful consideration around how to manage this transition from the perspective of reliable winter operations.

The results of the fuel and energy security assessment point to a number of options that may be considered by NYISO and stakeholders. It is premature to point to a specific set of recommended actions that flow from the fuel and energy security analysis described in this report. This is because the issue first warrants a deliberative review by NYISO and stakeholders of the potential consequence of cases with potential LOL events, their likelihood of occurrence, the potential ability/feasibility and cost associated with mitigating or eliminating the risks, and a careful weighing of the benefits and costs of taking specific actions to address them - whether through NYISO operating procedures, targeted resource or infrastructure additions, administrative actions by the state's electric and/or natural gas utilities, or changes to NYISO's wholesale markets. A full assessment of the costs and benefits of addressing risks arising under various cases analyzed is beyond the scope of this report.

5. Options

From Analysis Group's perspective, it is not clear that the magnitude and likelihood of the risks identified warrant a major NYISO-wide market design effort at this time; the most important challenges are associated with scenarios or disruptions that have a relatively low probability of occurrence, and/or are geographically concentrated on Long Island (an area at the forefront of development of new offshore wind and energy storage resources). Nevertheless, there are a wide range of potential options to consider that flow from the results of the analysis and the key levers driving circumstances that lead to potential LOL events, the experience with winter fuel and energy security efforts in other regions (e.g., ISO-NE and PJM), and the specific circumstances in New York. Potential options include:

Continued and expanded monitoring and analysis. The impact of severe winter conditions on power system operations in New York is highly dependent not only on the availability of fuel for generating resources, but on the portfolio of resources available, the level and shape of demand under winter peaks, and the various disruptions or contingencies that may occur during cold weather conditions. Continued and expanded monitoring of these conditions represents a clearly valuable endeavor for reliable system operations. For example, the reliance in New York on the flexibility afforded by dual fuel capability, particularly downstate, suggests continued or expanded vigilance in monitoring the practices of generating asset owners with respect to establishing initial winter fuel oil inventories and executing pre-season or in-season contracts with fuel oil suppliers for the reliable delivery (by barge and/or truck) of replenishment fuel on regular and as-needed bases. Moreover, a key uncertainty in the analysis is the actual expected availability of natural gas to support power generation under severe cold weather conditions. NYISO should continue to interact with interstate pipeline operators and the state's natural gas LDCs, and conduct analysis based on available data, to maintain an up-to-date understanding of the changing circumstances of natural gas infrastructure, LDC demand, and likely contractual flows out to neighboring regions.

Focus on the possible impacts of potential retirements in response to the proposed "peaker rule." As revealed in the modeling results, potential retirements in response to the proposed "peaker rule" could have detrimental impacts on winter system reliability if the capacity is not sufficiently replaced with development that can provide the same or similar level of energy and reserve contributions during winter operations. As NYISO evaluates the overall possible reliability impacts of potential retirements and resource fleet changes in response to the proposed "peaker rule," particular attention should be directed to assessing impacts on fuel and energy security in the state.

If continued monitoring indicates the potential for reliability risks related to fuel inventories in the future, further assess the adequacy of incentives for appropriate pre-season fuel oil inventory levels and/or replenishment arrangements. The current operational capability of oil-fired capacity downstate is critical to winter power system reliability in New York. NYISO already monitors inventories, use and replenishment for these units. Moreover, certain units are subject to mandatory oil-burn operations under specified temperature and/or gas system conditions. Nevertheless, given oil's importance, if the continued monitoring of fuel inventories identifies reductions in inventory levels in the future that may pose reliability risks to winter operations, NYISO and its stakeholders may want to evaluate the adequacy of current incentives for establishing appropriate pre-season inventory levels and replenishment arrangements.

Review the potential for geographically-targeted development of new renewable and energy storage resources required or incentivized through implementation of the CLCPA. There is little doubt that there will be a major expansion of advanced clean (low carbon) energy technologies over the next ten years. To the extent that winter fuel and energy security risks tend to be concentrated in downstate zones, NYISO may consider evaluating how the interconnection or installation of new renewable and energy storage resources in specific zones or locations on the bulk power system could provide ancillary winter reliability benefits. For example, an assessment of the magnitude, frequency and duration of potential LOL events in specific localities, and under plausible system conditions, could identify particular value associated with energy storage resources that meet certain technical specifications (size, discharge rate, and duration) that could mitigate or eliminate identified reliability risks. In a similar vein, to the extent the CLCPA warrants expansion of transmission system infrastructure (e.g., to move more renewable resources from upstate to downstate), NYISO could consider how to best plan for and design transmission expansion in a way that mitigates potential downstate fuel security issues.

Proactive scenario analysis of the potential impacts of the CLCPA. As noted previously, the state of New York is embarking on a period of unprecedented change in many of the critical demand and supply realities in the state; this suggests value in a proactive reliability-focused scenario assessment of New York's first ten years of CLCPA implementation, reviewing (a) potential changes in the magnitude and shape of power demand across all seasons under postulated scenarios of electrification of transportation and heating sectors; (b) the likely quantities, technical parameters, and interconnection locations of specific grid-connected and distributed renewable and energy storage resources through 2030; (c) the shape (or hourly generation profile) and effective load carrying capability of grid-connected and distributed solar, onshore wind, and offshore wind resources; and (d) the impact of these changing demand and supply hourly profiles on the residual resources needed to maintain power system reliability.

Continuous updating and refinement of energy and fuel security modeling. The results demonstrate that the flexibility afforded by dual fuel capability, particularly downstate, is of critical importance to reliable winter operations. The importance of this capability is expected to persist throughout the ongoing transition of the New York's resource fleet. The results of the analysis also highlight the potentially significant impacts of timely development of new renewable resources. In light of the ongoing transition of the resource fleet, the NYISO should consider continuing the development, refinement, and application of the fuel and energy security model as a tool for continued assessment of winter operational risks as the system and circumstances change over time. For example, the NYISO should consider periodic refreshing of the analysis herein (or certain key aspects thereof) to account for changes in system conditions over time. The NYISO should also consider utilizing the results of this analysis and the capability provided by the fuel and energy security model to identify certain key changes that could serve as leading indicators of potential future reliability and/or fuel security concerns (e.g., identifying the magnitude of dual fuel capability losses that can be sustained before adverse impacts to reliable winter operations arise). Such indicators could be used as part of ongoing, proactive monitoring to identify changes in system conditions that would trigger a need for engaging with stakeholders to assess whether further mitigating action is warranted, and, if so, identifying and evaluating potential remedial options.

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VIII. Glossary

BAU	Business as usual
Bcf	Billion cubic feet: a unit of natural gas
BIO	Biomass
BIT	Bituminous coal
C&I	Commercial and industrial
CARIS	Congestion Assessment and Resource Integration Study
CC	Combined cycle
CLCPA	Climate Leadership and Community Protection Act
ConEd	Consolidated Edison Company of New York, Inc.
CT	Combustion turbine
DF	Dual fuel
DMNC	Dependable Maximum Net Capability
Dth	Dekatherm: a unit of natural gas
EDD	Effective degree day
EDRP	Emergency Demand Response Program
EE	Energy efficiency
EFORd	Equivalent Forced Outage Rate on Demand
EIA	US Energy Information Administration
FERC	Federal Energy Regulatory Commission
GHG	Greenhouse gas
GT	Gas turbine
HQ	Hydro-Québec
ICAP	Installed capacity
IESO	Independent Electricity System Operation (Ontario)
ISO	Independent System Operator
ISO-NE	ISO New England Inc.
JE	Jet engine
LDC	Local natural gas distribution company
LI	Long Island (zone K)
LIPA	Long Island Power Authority
LOL	Loss of load
MMcf	Million cubic feet
MW	Megawatts
MWh	Megawatt hour
NG	Natural gas
NP	Nuclear power
NYC	New York City (zone J)
NYCA	New York Control Area
NYDPS	New York State Department of Public Service
NYISO	New York Independent System Operator, Inc.
NYSDEC	New York State Department of Environmental Conservation
NYSERDA	New York State Energy Research and Development Authority
OSW	Offshore wind
PJM	PJM Interconnection, L.L.C.
PS	Pumped storage
PV	Photovoltaic
RTO	Regional Transmission Organization
SCR	Special Case Resource
SENY	Southeastern New York (zones G-K)
SRS	2017 CARIS Phase 1 "System Resource Shift" case

ST	Steam turbine
SUN	Solar
UPNY	Upstate New York
UR	Uranium
WND	Wind
WT	Wind turbine

IX. Technical Appendices

A. Neighboring Regional Fuel Security Studies

	ISONE Operation Fuel-Security Analysis (OFSA)	PJM Fuel Security Analysis
Study Released Study Year System Stress Time Period Modeling Approach Number of Scenarios	January 2018 Winter 2024/2025 90-day winter period Spreadsheet count model 23	December 2018 Winter 2023/2024 14-day weather event in winter Full Economic Dispatch model 324
Summary of Results	Load shedding occurred in 19 of 23 cases Public requests for energy conservation occurred in 22 or 23 cases 1 of 23 cases caused no emergency actions	"The PJM system is reliable today and will remain reliable into the future. The analysis results showed some risks and vulnerabilities associated with fuel security. The key variables that have the most impact are: On-site fuel inventory, Oil deliverability, Availability of non-firm natural gas service, Location of a pipeline disruption, and Pipeline configuration"
Takeaways Based on Study Results	1. The ISO-NE region is vulnerable to winter season-long outages of major energy facilities (For example, a Millstone nuclear outage, or Canaport LNG outage) 2. The power system is reliant on stored fuels, such as LNG, and electricity. Recommends additional dual-fuel capacity, acknowledging the permitting and environmental challenges of moving forward with new dual-fuel infrastructure. 3. The timely availability of fuel to electric generators and delivery logistics are key for reliability and the avoidance of load shedding. 4. Increased renewables, LNG, and imports reduce reliability stress on the system. However, the increased penetration of renewables drives the retirement of coal- and oil-fired generation. LNG and imports will need to be increased as a counter balance. Conclusion: "Taken together, the study results suggest that New England could be headed for significant levels of emergency actions..."	Conclusion: "While there is no imminent threat, fuel security is an important component of ensuring reliability and resilience – especially if multiple risks come to fruition. The findings underscore the importance of PJM exploring proactive measures to value fuel security attributes, and PJM believes this is best done through the competitive wholesale markets."

Sources:
[1] ISO-NE, Operational Fuel-Security Analysis, For Discussion, January 17, 2018.
[2] PJM, Fuel Security Analysis: A PJM Resilience Initiative, December 17, 2018.

B. Input Data to Natural Gas and Electric System Models

1. 2017 CARIS Phase 1 System Resource Shift Case Data

The starting point for our electric sector modeling is the "System Resource Shift" case from the 2017 CARIS Phase 1 analysis. On the supply side, the "System Resource Shift" case starts with the 2017 Gold Book and then makes several resource mix adjustments. The detailed unit specific adjustments specified as part of the "System Resource Shift" case are detailed in Table B1 below. Notably, the "System Resource Shift" case assumes the retirement of all New York's coal resources by 2020 and the retirement of Indian Point 2 and 3 prior to winter 2023/2024.

Table B1: 2017 CARIS Phase 1 System Resource Shift Case Resource Adjustments Applicable to the Winter 2023/2024 Study Period

Additions

Resource	Technology	Fuel	Dual Fuel	Zone	Nameplate Capacity (MW)	Year In-Service
Greenidge 4	ST	NG	-	C	106	2017
Ogdensburg	CC	NG	-	E	79	2017
Arkwright Summit Wind	WT	WND	-	A	78	2017
CPV Valley	CC	NG	YES	G	678	2018
Bayonne GT Uprate	JE	NG	YES	J	116	2018
Taylor Biomass	CC	BIO	-	G	19	2018
Copenhagen Wind	WT	WND	-	E	80	2018
Shoreham Solar	PV	SUN	-	K	25	2018
Eight Point Wind Energy	WT	WND	-	C	101	2018
Cricket Valley Energy	CC	NG	-	G	1,020	2019
Cassadaga Wind	WT	WND	-	A	126	2019
Total:					**2,428**	

Retirements

Resource	Technology	Fuel	Dual Fuel	Zone	Nameplate Capacity (MW)	Year Assumed Retired
Freeport CT 1	GT	NG	YES	K	48	2017
Somerset	ST	BIT	-	A	686	2019
Cayuga 1	ST	BIT	-	C	152	2019
Cayuga 2	ST	BIT	-	C	150	2019
Indian Point 2	NP	UR	-	H	1,000	2020
Indian Point 3	NP	UR	-	H	1,041	2021
Total:					**3,077**	

The "System Resource Shift" case further assumes the integration of renewable energy and energy efficiency to satisfy objectives of the Clean Energy Standard, as it was when the 2017 CARIS Phase 1 analysis was developed, on an accelerated timeline. [60] The "System Resource Shift" case was designed such that 49% of New York's energy requirements were projected to be met by renewables by 2026.[61] To meet these goals, the "System Resource Shift" case assumes the entry of 8,475 MW (nameplate) wind and solar resources by the 2023/2024 winter.[62] (See Table B2 for the zonal breakout of renewable capacity added.)

Table B2: 2017 CARIS Phase 1 System Resource Shift Case New Renewable Entry Applicable to the Winter 2023/2024 Study Period

Zone	Resource	2017	2018	2019	2020	2021	2022	2023	2024	Total 2017-2024
	Land Wind		89	445	364	66	278	95		1,337
A	Solar							894		894
	Offshore Wind									0
	Land Wind									0
B	Solar									0
	Offshore Wind									0
	Land Wind									0
C	Solar						1,082			1,082
	Offshore Wind									0
	Land Wind									0
D	Solar									0
	Offshore Wind									0
	Land Wind					175		137	537	849
E	Solar									0
	Offshore Wind									0
	Land Wind			55	65	185	82	80	240	707
F	Solar				605	502			1,804	2,911
	Offshore Wind									0
	Land Wind			41	34	72		32		179
G	Solar					127		195		322
	Offshore Wind									0
	Land Wind									0
H	Solar					11				11
	Offshore Wind									0
	Land Wind									0
I	Solar									0
	Offshore Wind									0
	Land Wind									0
J	Solar									0
	Offshore Wind									0
	Land Wind								77	77
K	Solar					106				106
	Offshore Wind									0
	Land Wind	0	89	541	463	498	360	344	854	3,149
NYISO	Solar	0	0	0	605	746	1,082	1,089	1,804	5,326
	Offshore Wind	0	0	0	0	0	0	0	0	0
	Total	**0**	**89**	**541**	**1,068**	**1,244**	**1,442**	**1,433**	**2,658**	**8,475**

[60] The 2017 CARIS Phase 1 "System Resource Shift" case assumptions correspond to a "50 by 30" standard established by the Clean Energy Standard. 2017 CARIS Phase 1 Report, FN 38.

[61] 2017 CARIS Phase 1 Report, page. 38.

[62] 2017 CARIS Phase 1 Report, page. 40.

As discussed in Section III.C.2, the model incorporates wind and solar production profiles directly from the 2017 CARIS Phase 1 "System Resource Shift" case. The underlying weather shape for the 2017 CARIS Phase 1 analysis is based on the year 2002.[63] As such, the coldest 17 -day period in the winter 2002 was identified, and the predicted renewable output from the 2017 CARIS Phase 1 SRS case during the 17 coldest days in the winter 2023/2024 was used as the wind and solar output in the model.[64] The renewable generation output as part of the 2017 CARIS Phase 1 "System Resource Shift" case was made available on an hourly basis at the zonal level by renewable type: onshore wind, solar, and offshore wind. Behind-the-meter solar and utility scale solar were modeled together in the 2017 CARIS Phase 1 analysis, and load data was unadjusted for behind-the-meter solar. The load data from the 2017 CARIS Phase 1 "System Resource Shift" case was measured at the hourly level, aggregated by zone, and included energy efficiency adjustments. The 2017 CARIS Phase 1 "System Resource Shift" case assumes energy efficiency reduces 17,186 GWh of total energy in 2024 with a total winter peak load reduction of 1,638 MW. For a further discussion of our load modeling see Section III.B.3.

2. Generator Data

In addition to the public data produced as part of the 2017 CARIS Phase 1 analysis, the NYISO made additional data available to inform the modeling efforts and help align the modeling effort for this study with historic operating experience. NYISO provided operational oil storage and replenishment data, guidance on the operations of nuclear, hydro, pumped storage, battery, and biomass/refuse resources.

Across all resource types, excluding wind and solar, the NYISO provided resource-specific winter Dependable Maximum Net Capability (DMNC) values and resource-specific EFORd derate adjustments. The capacity modeled for all units is the resource-specific DMNC, as adjusted to reflect winter-specific derates. For nuclear facilities, hydro run-of-river facilities, biomass, refuse, flywheel resources, the model assumed constant production throughout the 17-day modeling period at winter DMNC value adjusted to reflect winter-specific derates.

Pumped storage, large pondage hydro, and existing batteries are modeled using hourly profiles from NYISO based on historic and expected operational observations. Specifically, the Niagara facility is assumed by the model to operate for 12 hours at a peak production of 2,200 MW per hour between 9 AM and 9 PM. From 9 PM to 9 AM, the model assumes Niagara operates at 1,000 MW per hour. The model assumes that the four units at the Blenheim-Gilboa pumped storage facility generate approximately 1,165 MW per hour between 3 PM and 9 PM, and then pumps for nine hours between 10 PM and 7 AM.

The model also assumes the addition of 350 MW of new battery storage capacity being in-service by the winter 2023/2024 period,[65] of which 300 MW are sited in zone J, 20 MW in zones G-I, 10 MW in zone F, and 20 MW in zones A-E. The model assumes that these new battery storage facilities run on a daily charge/discharge cycle where batteries discharge at capacity between 4 PM and 8 PM, and charge during the night between 1 AM and 5 AM, using a round-trip efficiency of 85%.

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[63] 2017 CARIS Phase 1 Report Appendices, page. 4.

[64] The coldest period during the calendar year 2002 was identified using historic weather data from NYISO. The coldest period was between December 1-17, 2002, so the model uses predicted wind and solar output from December 1-17, 2024.

[65] See State of New York Public Service Commission, Case 18-E-0130 - In the Matter of Energy Storage Deployment Program, Order Establishing Energy Storage Goal and Deployment Policy, Issued and Effective: December 13, 2018, p. 55.

The model also includes load reduction capability made available by SCRs and the EDRP. The model assume a maximum capability from SCRs/EDRP of 893 MW, based on the NYISO's 2019 Gold Book.[66] The model assumes that SCRs/EDRP can be activated for a maximum of four hours per day, and that over the entire duration of the 17-day modeling period, these resources can only be deployed on five days.[67] The model dispatches SCRs/EDRP zonally only after reducing energy-only exports to ISO-NE.

The oil inventory and replenishment data used in the model was based on fuel survey information reported by generators to the NYISO. Data provided included maximum inventory capacity, replenishment capability, and historic inventory levels for dual fuel and oil only resources. Resource-specific starting inventory levels were determined based on average December inventory levels over the past two years, by zone and by replenishment type (barge or truck). The model assumes that units will refill when their fuel ran down to 50% of the assumed initial inventory. The model assumes the replenishment capability reported by resources in the fuel survey responses submitted to the NYISO to determine both the rate and quantity of inventory replacement available during the 17-day modeling period.

3. LDC Design Day Demand

The LDCs file winter supply information each winter with the New York State Department of Public Service (NY DPS).[68] Table B3 below shows the 2018-2019 winter peak day capability for upstate and downstate LDCs collectively. The capability designated as coming from pipelines was used to calibrate the modeled weather conditions and LDC demand relationship.

[66] NYISO 2019 Gold Book, p. 38.

[67] In a separate analysis at the request of stakeholders, a set of "unrestricted SCR" cases were modeled in which SCRs/EDRP were available for 6 hours per activation for the entire 17-day modeling period without any restriction on the number of days these resources could be activated. The results showed little to no impact on case results across scenarios and physical disruptions.

[68] See, for example, New York State Department of Public Service, Report on the New York State Electric & Gas Supply Readiness for 2018-2019 Winter, Case No. 18-M-0272, "New York State Electric & Gas and Rochester Gas and Electric 2018-2019 Winter Supply Plan," July 16, 2018, available at http://documents.dps.ny.gov/public/MatterManagement/CaseMaster.aspx?MatterCaseNo=18-M-0272&submit=Search.

Table B3: New York DPS Winter 2018-19 Design Day Capability Summary Table

	NYISO Zone Group Capability		
	Upstate (MMcf)[1]	Downstate (MMcf)[2]	Total Design Day Capability (MMcf)
Zones Covered	A-F	G-K	
Pipeline[3]	1,964	3,306	5,270
Storage[4]	1,120	838	1,959
LNG	0	395	395
Other[5]	60	67	126
Total Design Day Capability (MMcf)	**3,143**	**4,605**	**7,749**

Notes:
[1] Upstate includes Corning Natural Gas Corporation, National Fuel Gas Distribution Corporation, National Grid: Niagara Mohawk, NYSEG, and Rochester Gas & Electric LDCs.
[2] Downstate includes Central Hudson, Conslidated Edision and National Grid: Brooklyn Union and KeySpan
[3] Pipeline includes flowing supplies, less NFGSC fuel = National Fuel Gas Supply Co. natural gas pipeline, winter peaking service = "City Gate Delivered by Others and In-Territory Supplies (not LNG or CNG)", total marketer provided supplies, and recallable capacity (AMAs). Assumes all ConEd gas comes from pipeline.
[4] Storage includes storage withdrawals and CNG.
[5] Other includes cogen supplies, local production = "Local Production, landfill gas, renewables, etc. delivered directly into the LDC distribution system", and renewable gas = "Local Production, landfill gas, renewables, etc. delivered directly into the LDC distribution system".

Sources:
[A] Central Hudson Gas & Electric Corporation, Case 18-M-0272 - Winter Supply 2018-19 Forms, October 8, 2018, Table 1.
[B] Consolidated Edison Company, Inc., Case 18-M-0272 - Winter Supply Review Data Request, July 16, 2018, Table 1.
[C] Corning Natural Gas Corporation, Case 18-M-0272 - Winter Supply Review Data Request, July 5, 2018, Table 1.
[D] National Fuel Gas Distribution Corporation, Case 18-M-0272 - Winter Supply Review Data Request, July 16, 2018, Table 1.
[E] Brooklyn Union and KeySpan: National Grid, Case 18-M-0272 - Winter Supply 2018-19 Forms, November 9, 2018, Table 1.
[F] Niagara Mohawk: National Grid, Case 18-M-0272 - Winter Supply 2018-19 Forms, September 10, 2018, Table 1.
[G] New York State Electric & Gas and Rochester Gas and Electric, Case 18-M-0272 - 2018-2019 Winter Supply Plans September 2018 Update, Table 1.
[H] Consolidated Edison, Inc. and Consolidated Edison Company of New York, Inc., Form 10-k, for the fiscal year ended December 31, 2017, p. 24.

4. S&P Global Market Intelligence Data

Data from S&P Global Market Intelligence was relied on for unit specific heat rates (btu/kWh) for the fossil fleet of generation resources. The heat rates are used in order to rank the relative efficiency of the fossil plants and determine their order in our stacking analysis.[69]

[69] S&P Global Market Intelligence defines their published heat rate as: "Unit level heat rate is calculated based off of the unit's heat input and net generation. Plant level heat rate is based off of the sum of all unit heat input and net generation. Where unit level operating heat input data is reported

Additionally, S&P Global Market Intelligence data was used in the modeling of New York's natural gas sector. As discussed above, in order to model the relationship between LDC gas demand and weather, daily historical data on LDC and end user gas demand from S&P Global Market Intelligence was utilized. This data provides information on the daily historical scheduled capacity at each pipeline point. This analysis used data from pipeline points designated as delivery to LDC or end-user. There are multiple nomination cycles, both day-ahead and intraday, in which LDCs can adjust their scheduled capacity of natural gas for delivery.[70] For the purposes of this analysis, data from the intraday 3 nomination cycle was used because it is the final intraday nomination cycle, and therefore represents the most accurate information on the final amount of natural gas delivered at the end of any given day.

5. EIA Natural Gas Pipeline Data

New York State gas supply was modeled based on data provided by EIA, in its "U.S. State-to-State Capacity" dataset.[71] Assumed gas flows in and out of New York were developed over the following interstate pipelines:

- Algonquin Gas Trans Co
- Central New York Oil and Gas Company
- Columbia Gas Trans Corp
- Dominion Transmission Co.
- Empire Pipeline Inc
- Iroquois Pipeline Co.
- National Fuel Gas Supply Co.
- Norse Pipeline Co.
- North Country P L Co.
- Penn York Energy Corp.
- St Lawrence Gas
- Tennessee Gas Pipeline Co.
- Texas Eastern Trans Corp.
- Transcontinental Gas P L Co.

Across all the pipelines identified above, the total natural gas import capacity into New York State is 13,923 MMcf/d based on EIA data. The total export capacity from New York State to neighboring states and provinces is 7,136 MMcf/d.[72] The pipelines listed above and their associated import and export capacity only represent *interstate* natural gas pipelines. There are additional intra-state pipelines not included in this list, but because this analysis assumes gas is fungible across New York State, subject to certain downstate operational limitations, no assumptions about the capacity of such intrastate pipelines was developed for this study. The study also assumes that no new import or export pipeline capacity is added to New York State prior to the winter 2023/2024 period.

there will be some variance in the heat rate of each unit at a single power plant. In the case of CCs, all units will have the same heat rate as the plant level record. A default heat rate is applied to all fossil-fired units where a reported source is unavailable." S&P Global Market Intelligence, "Generation Supply Curve: Heat Rate," available at https://platform.mi.spglobal.com/help/Generation_Supply_Curve.htm.

[70] FERC, Coordination of the Scheduling Processes of Interstate Natural Gas Pipelines and Public Utilities, Order No. 809, 151 FERC ¶ 61,049 (April 16, 2015), available at https://www.ferc.gov/whats-new/comm-meet/2015/041615/M-1.pdf.

[71] EIA, Natural Gas Pipeline Data, "U.S. State-to-State Capacity," available at https://www.eia.gov/naturalgas/data.php.

[72] Some of these import/export capacity values are on bidirectional pipelines.

6. Maximum Natural Gas Supply for Generation

The natural gas system supply capability developed for this study is based the capacities provided by EIA, as detailed above. These import and export capacities in conjunction with the NYISO's observed interstate gas flows and a review of LDC commitments are used to determine the total amount of gas available to New York State for all purposes (heating, industrial, electric power generation, etc.). As see in Table B4, this analysis assumes that the net gas imports from PJM and Ontario total approximately 10,246 MMcf/d. The study also assumes that all the interstate pipelines connecting New York to New England are fully committed for export. As a result, it is assumed that 4,087 MMcf/d leave New York for New England, leaving 6,159 MMcf/d for all in New York State gas demands. After accounting for 5,270 MMcf/d reserved for LDCs, the remaining balance of 889 MMcf/d is assumed available for use by electric generators. The study assumes that no liquefied natural gas (LNG), satellite, or underground natural gas storage capacity is available to electric generators, as this capacity is fully committed to LDC and other industrial customers.

Table B4: New York State Modeling Period Gas Supply and Demand (MMcf/d)

Gas Supply/Demand	MMcf/d	Calculation	Source
Modeling Period Supply			
Max New York State Imports from PJM	9,846	[A]	EIA
Expected New York State Net Imports from Ontario	400	[B]	NYISO
Gas Available within New York	***10,246***	***[C] = [A] + [B]***	
Modeling Period Demand			
Max Exports to New England	(4,087)	[D]	EIA
New York Design Day LDC Demand from Pipeline Gas	(5,270)	[E]	NYDPS
Total Outflows/LDC Demand	***(9,357)***	***[F] = [D]+[E]***	
Max Gas Available for Electric Generation in New York	**889**	**[G] = [C] + [F]**	
Equivalent MW of Gas Generation Capacity each Hour at 8 MMBtu/MWh Heat Rate	**4,804**	**[H] = [G] * 5.4**	

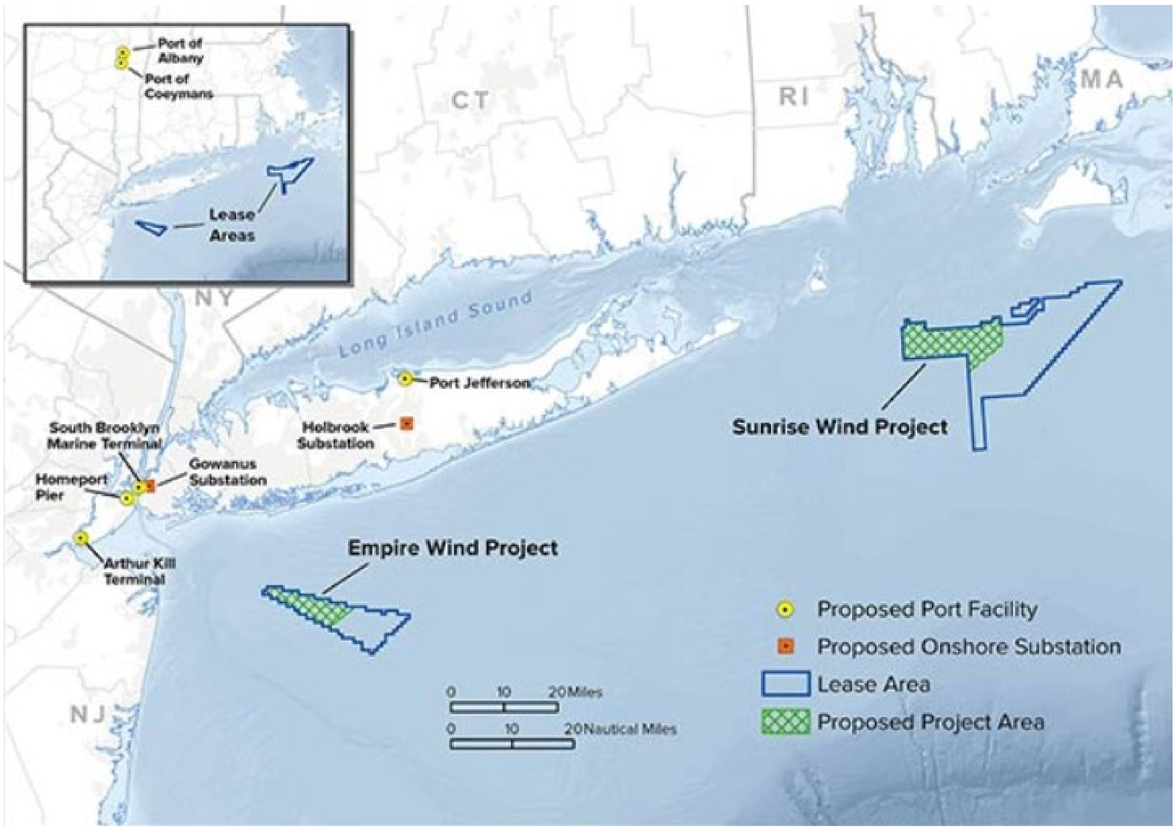
Note:
[1] Design Day LDC Demand aggregated from Winter Supply forms and 10-K financials for New York State LDCs.

Sources:
[1] EIA, State to State Pipeline Capacity, January 31, 2019.
[2] NYDPS/NYPSC, Case 18-M-0272 - Winter Supply 2018-2018 Forms, Table 1.
[3] Consolidated Edison, Inc. and Consolidated Edison Company of New York, Inc. Form 10-K, for the fiscal year ended December 31, 2017, p. 24.

7. New Offshore Wind Assumptions

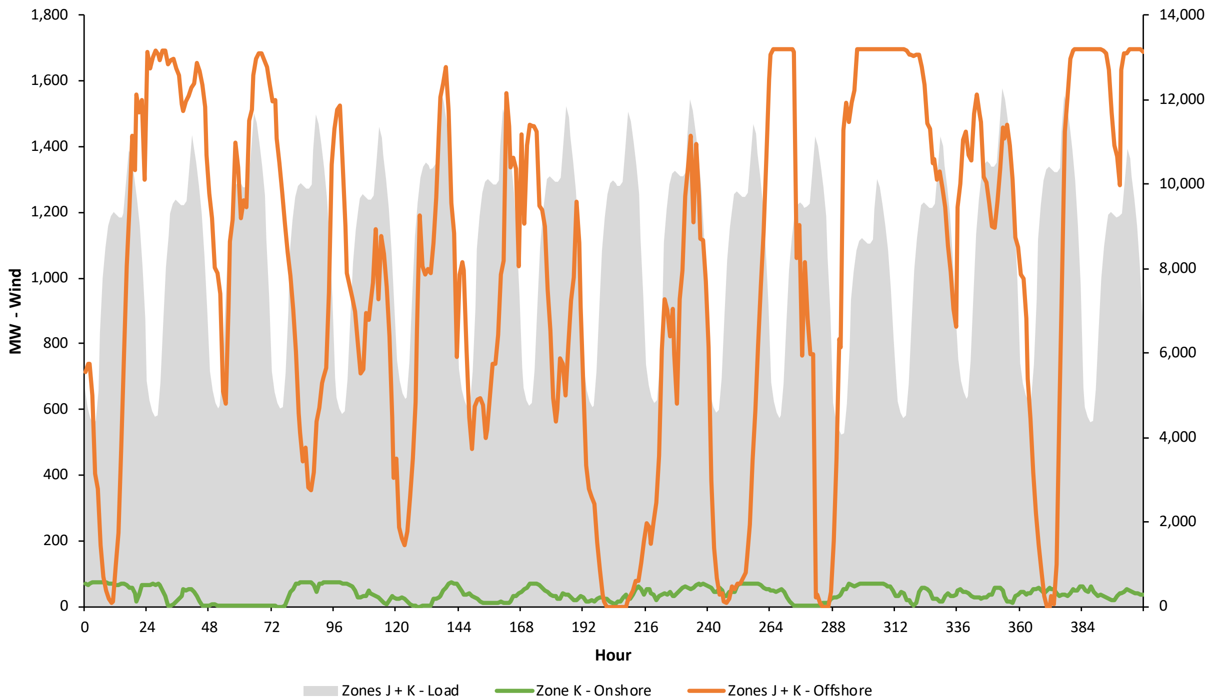
In 2018, NYSERDA solicited bids for new offshore wind development. The winning bids were submitted by Empire Wind, which plans to build an 816 MW wind farm south of Long Island, and Sunrise Wind, which plants to build an 880 MW wind farm east of Long Island. Figure B1 shows the proposed location of the two projects.

Figure B1: Map of Empire and Sunrise Offshore Wind Projects



In order to analyze the effect of these two wind farms on NYISO fuel security, both projects were modeled in additional alternate case runs. Since no operational data yet exists for these projects or any offshore wind farms in New York waters, data from the WIND toolkit developed by the National Renewable Energy Laboratory (NREL) was used. This data provides historical wind speed and power output for offshore wind locations. Power output data was extracted for wind points within the proposed project areas (shown above in Figure B1) during the first 17 days of January 2012 to provide an estimate of the potential wind speeds during the 17-day modeling period. The power output profiles were then scaled up to represent the 1,696 MW total capacity associated with the proposed Empire Wind and Sunrise Wind projects. Figure B2 shows the modeled hourly output of these offshore wind projects as compared to load during the modeling period.

Figure B2: Offshore Wind Generation Profiles



Sources:

[1] NYISO/AG Fuel Security Model.

[2] Offshore wind profiles for the locations of contracted Zone J and K offshore wind are from the NREL Wind Integration National Dataset (WIND)Toolkit, available at https://www.nrel.gov/grid/wind-toolkit.html. For additional detail on the underlying power curves, see NREL, "Validation of Power Output for the WIND Toolkit," September 2014, pp. 4-5.

C. Evaluation Process for Developing Cases of Interest

1. Step One: Determine Probability of Occurrence

	Winter 2023/2024 Scenarios							
Disruptions	**Scenario 1:** Initial Conditions + IM900	**Scenario 2:** Initial Conditions + IM900 + PK	**Scenario 3:** Initial Conditions + IM0	**Scenario 4:** Initial Conditions + IM0 + PK	**Scenario 5:** Initial Conditions + IM900 + PK + NGR	**Scenario 6:** Initial Conditions + IM0 + PK + REN	**Scenario 7:** Initial Conditions + IM0 + PK + NGR	**Scenario 8:** Initial Conditions + REN + IM0 + PK + NGR
1. No Disruptions (Starting Conditions)								
2. SENY Deactivation								
3. High Outage								
4. Nuclear Outage								
5. No Truck Refill								
6. No Barge Refill								
7. No Refill								
8. Non-Firm Gas Unavailable (F-K)								
9. Low Fuel Inventory								
10. Non-Firm Gas Unavailable (NYCA)								
11. Non-Firm Gas Unavailable (NYCA) + SENY Deactivation + No Refill								

Probability: Assessed qualitatively relative to typical construction of operational assessment scenarios, grouped as follows:

- Highly unlikely to occur - probability far outside typical conditions used in system operational assessments
- Probability *meaningfully less likely than* typical conditions used in system operational assessments
- Probability on the order of typical conditions used in system operational assessments

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

IM900 = 900 MW Capacity Imports.

IM0 = 0 MW Capacity Imports.

PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

2. Step Two: Determine Consequence and Ease of Mitigation

Disruptions	Winter 2023/2024 Scenarios							
	Scenario 1: Initial Conditions + IM900	**Scenario 2:** Initial Conditions + IM900 + PK	**Scenario 3:** Initial Conditions + IM0	**Scenario 4:** Initial Conditions + IM0 + PK	**Scenario 5:** Initial Conditions + IM900 + PK + NGR	**Scenario 6:** Initial Conditions + IM0 + PK + REN	**Scenario 7:** Initial Conditions + IM0 + PK + NGR	**Scenario 8:** Initial Conditions + REN + IM0 + PK + NGR
1. No Disruptions (Starting Conditions)	White	White	White	White	White	White	White	Red
2. SENY Deactivation	White	White	White	White	White	White	Yellow	Red
3. High Outage	White	White	White	White	White	Yellow	Red	Red
4. Nuclear Outage	White	White	White	White	White	Yellow	Red	Red
5. No Truck Refill	White	White	White	White	White	Yellow	Red	Red
6. No Barge Refill	White	White	White	White	Red	Yellow	Red	Red
7. No Refill	White	White	Red	Red	Red	Red	Red	Red
8. Non-Firm Gas Unavailable (F-K)	White	White	Yellow	Yellow	White	Red	Yellow	Red
9. Low Fuel Inventory	White	White	Red	Red	Yellow	Red	Red	Red
10. Non-Firm Gas Unavailable (NYCA)	Red	Red	Red	Red	Red	Red	Red	Red
11. Non-Firm Gas Unavailable (NYCA) + SENY Deactivation + No Refill	Red	Red	Red	Red	Red	Red	Red	Red

Consequence: Assessed based on magnitude, duration, and frequency of loss of load, grouped as follows:

- White: Loss of load zero or less than 100 MW, with short duration (less than 4 hours), that is infrequent (not more than two events over cold snap)
- Yellow: Loss of load between 100 and 1,500 MW, with moderate duration (up to 12 hours), that is not infrequent (two or three events over cold snap)
- Red: Loss of load greater than 1,500 MW OR between 100 and 1,500 MW with longer duration (more than 12 hours) OR between 100 and 1,500 MW that is frequent (more than three events over cold snap)

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

IM900 = 900 MW Capacity Imports.

IM0 = 0 MW Capacity Imports.

PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

3. Step Three: Combined Assessment to Develop Cases of Interest

Physical Disruptions	Winter 2023/2024 Scenarios							
	Scenario 1: Initial Conditions + IM900	**Scenario 2:** Initial Conditions + IM900 + PK	**Scenario 3:** Initial Conditions + IM0	**Scenario 4:** Initial Conditions + IM0 + PK	**Scenario 5:** Initial Conditions + IM900 + PK + NGR	**Scenario 6:** Initial Conditions + REN + IM0 + PK	**Scenario 7:** Initial Conditions + IM0 + PK + NGR	**Scenario 8:** Initial Conditions + REN + IM0 + PK + NGR
1. No Disruptions (Starting Conditions)								
2. SENY Deactivation								
3. High Outage						LI Only	LI Only	
4. Nuclear Outage								
5. No Truck Refill								
6. No Barge Refill								
7. No Refill			LI Only	LI Only				
8. Non-Firm Gas Unavailable (F-K)			LI Only					
9. Low Fuel Inventory			LI Only	LI Only	LI Only	LI Only		
10. Non-Firm Gas Unavailable (NYCA)								
11. Non-Firm Gas Unavailable (NYCA) + SENY Deactivation + No Refill								

Note: The scale of the axes are equal in all cells. The y-axis is set to have a maximum of 16,000 MW.

Combined Assessment: Based on qualitative assessments of Probability, Consequence, and ease of Mitigation, grouped as follows:

- Consequence 0-100 MW or probability extremely low (far outside normal operational assessments)
- Consequence 100 - 1,500 MW, of moderate duration/frequency, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability low (meaningfully less likely than normal operational assessments)
- Consequence greater than 1,500 MW, and probability on the order of normal operational assessments

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

IM900 = 900 MW Capacity Imports.

IM0 = 0 MW Capacity Imports.

PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

4. Full Heat Map of Results and Emergency Actions Taken

Physical Disruptions	Winter 2023/2024 Scenarios							
	Scenario 1: Initial Conditions + IM900	**Scenario 2:** Initial Conditions + IM900 + PK	**Scenario 3:** Initial Conditions + IM0	**Scenario 4:** Initial Conditions + IM0 + PK	**Scenario 5:** Initial Conditions + IM900 + PK + NGR	**Scenario 6:** Initial Conditions + REN + IM0 + PK	**Scenario 7:** Initial Conditions + IM0 + PK + NGR	**Scenario 8:** Initial Conditions + REN + IM0 + PK + NGR
1. No Disruptions (Starting Conditions)						Day 15	Day 9	Day 9
2. SENY Deactivation (1000 MW)					Day 3	Day 15	Day 9	Day 6
3. High Outage			Day 15	Day 15	Day 2	Day 15	Day 3	Day 3
4. Nuclear Outage		Day 9		Day 15	Day 2	Day 15	Day 8	Day 3
5. No Truck Refill			Day 7	Day 6	Day 3	Day 15	Day 9	Day 3
6. No Barge Refill		Day 15	Day 16	Day 15	Day 9	Day 15	Day 7	Day 6
7. No Refill	Day 15	Day 15	Day 15	Day 15	Day 8	Day 9	Day 6	Day 3
8. Non-Firm Gas Unavailable (F-K)	Day 8	Day 8	Day 9	Day 15	Day 8	Day 3	Day 15	Day 3
9. Low Fuel Inventory	Day 16	Day 16	Day 10	Day 10	Day 15	Day 10	Day 10	Day 6
10. Non-Firm Gas Unavailable (NYCA)	Day 9	Day 2	Day 3	Day 2	Day 2	Day 2	Day 2	Day 2
11. Non-Firm Gas Unavailable (NYCA) + SENY Deactivation + No Refill	Day 2	Day 2	Day 2	Day 2	Day 2	Day 1	Day 2	Day 1

- No identified concerns
- Curtailing of energy-only exports to ISO-NE
- SCR/EDRP activation
- Reserve shortage
- Potential for loss of load (first occurring after Day 7)
- Potential for loss of load (first occurring on or before Day 7)

Note: White text indicates a concern that is confined to occurring on Long Island only

Scenario Key

REN = Delayed construction of new renewables, such that solar capacity is reduced to 38.5% and wind capacity is reduced to 48% of System Resource Shift assumed levels.

IM900 = 900 MW Capacity Imports.

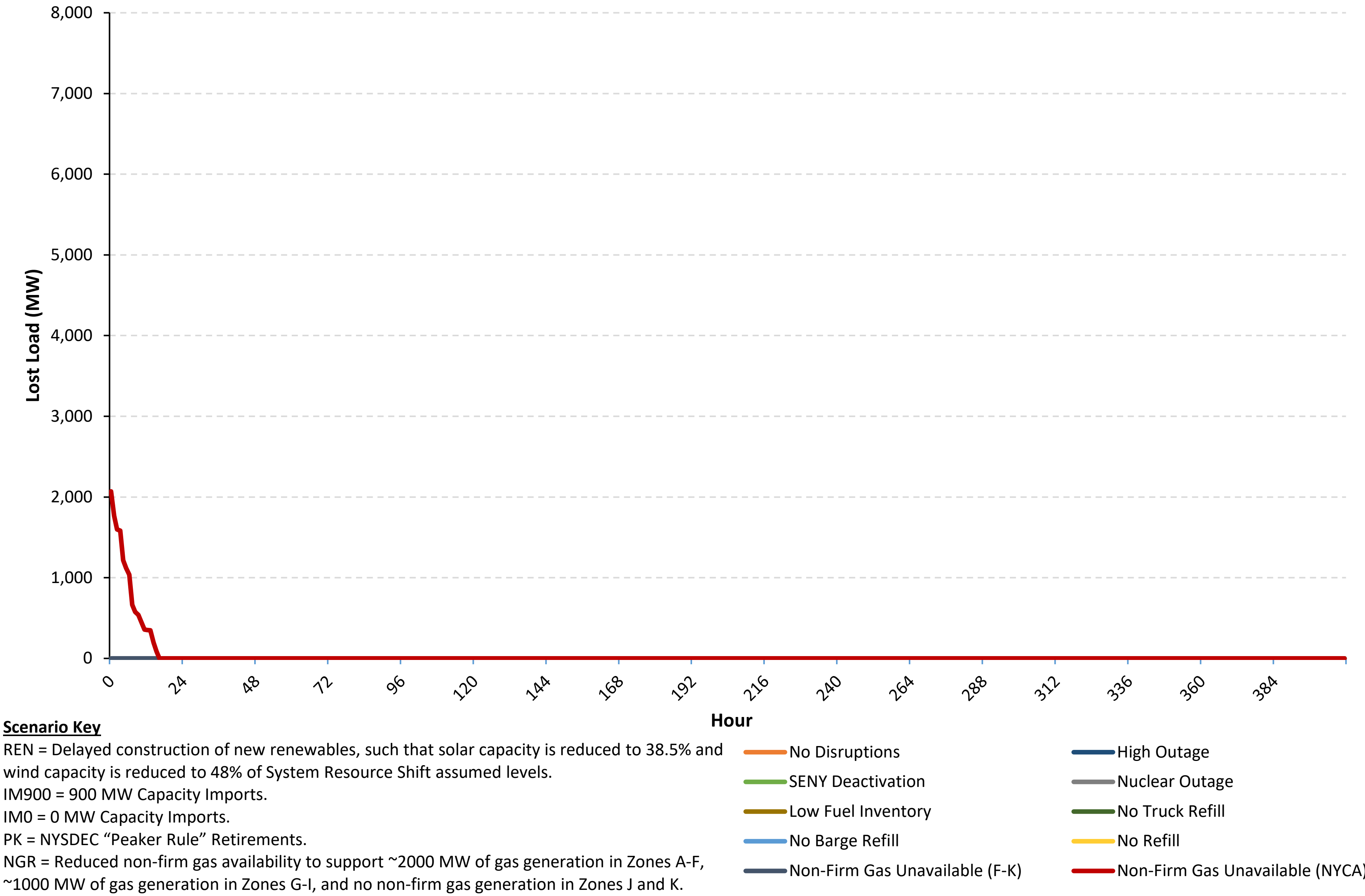
IM0 = 0 MW Capacity Imports.

PK = NYSDEC "Peaker Rule" Retirements.

NGR = Reduced non-firm gas availability to support ~2000 MW of gas generation in Zones A-F, ~1000 MW of gas generation in Zones G-I, and no non-firm gas generation in Zones J and K.

D. Loss of Load Duration Curves for all Scenarios and Physical Disruptions

NYCA
Lost Load Duration (MWh)
Scenario 1: Initial Conditions + IM900



Scenario Key
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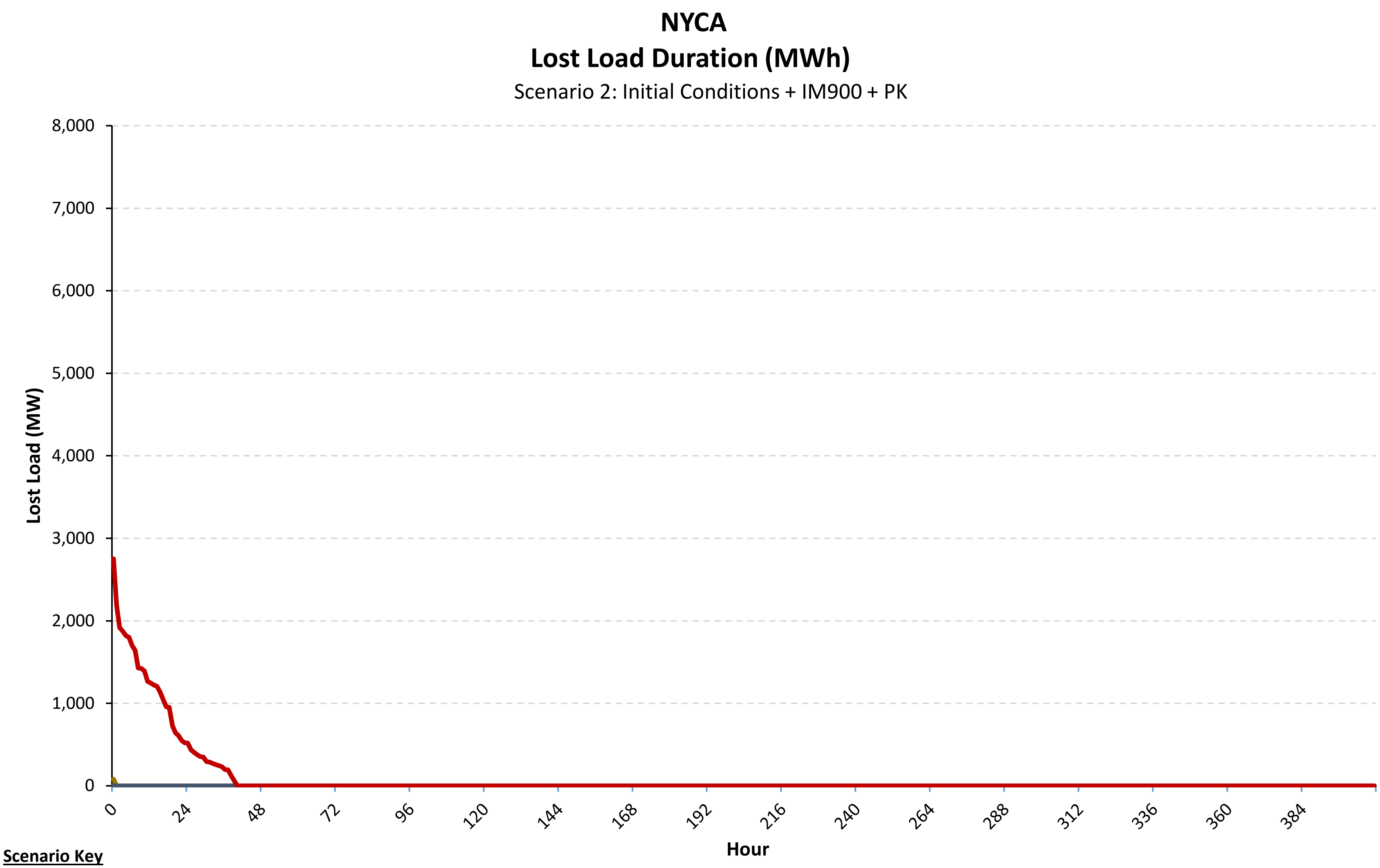

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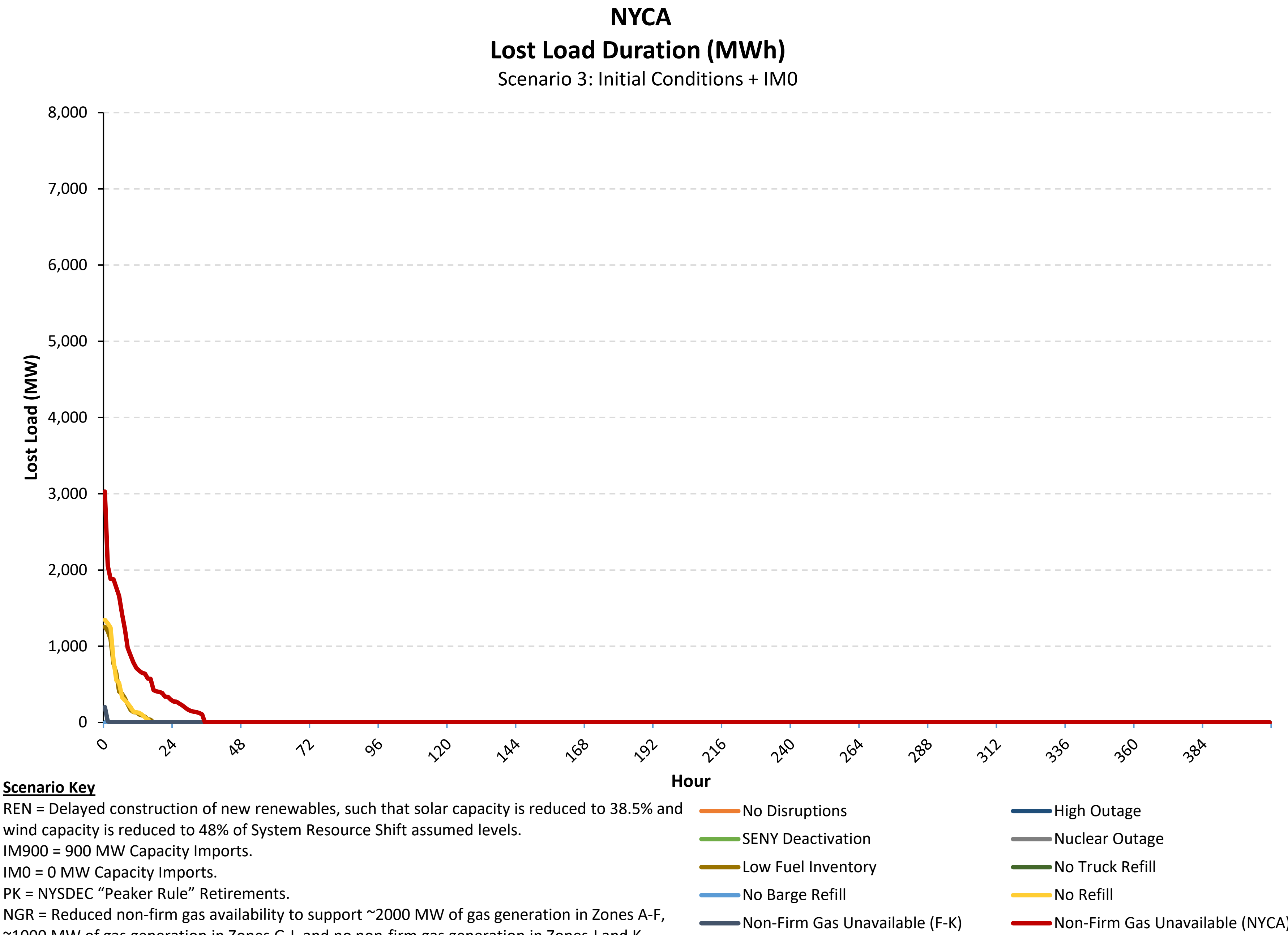
- No Disruptions
- SENY Deactivation
- Low Fuel Inventory
- No Barge Refill
- Non-Firm Gas Unavailable (F-K)
- High Outage
- Nuclear Outage
- No Truck Refill
- No Refill
- Non-Firm Gas Unavailable (NYCA)



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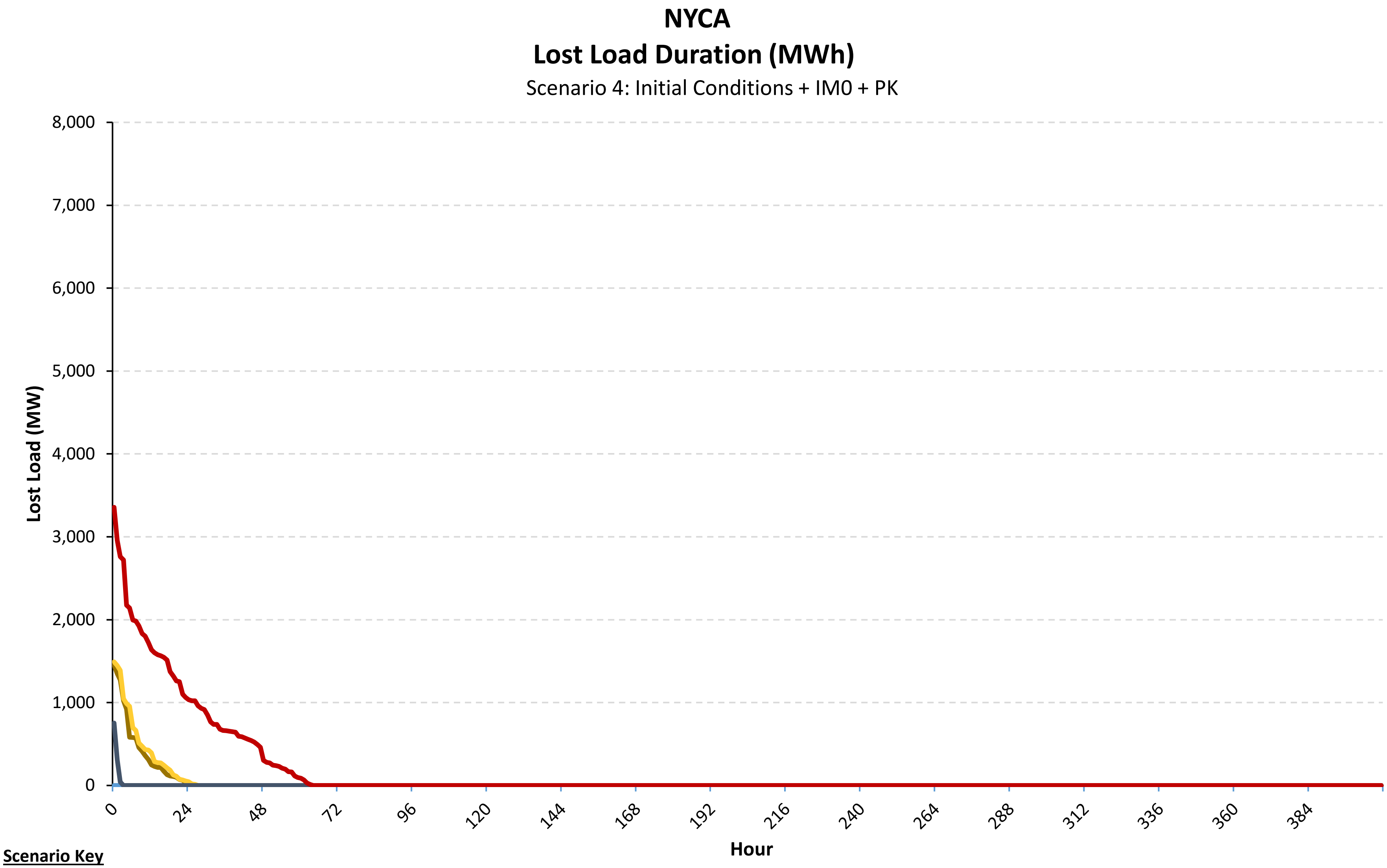

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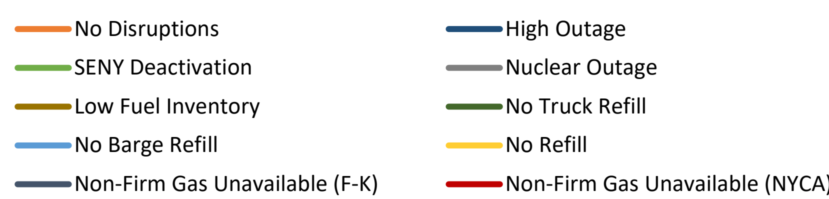
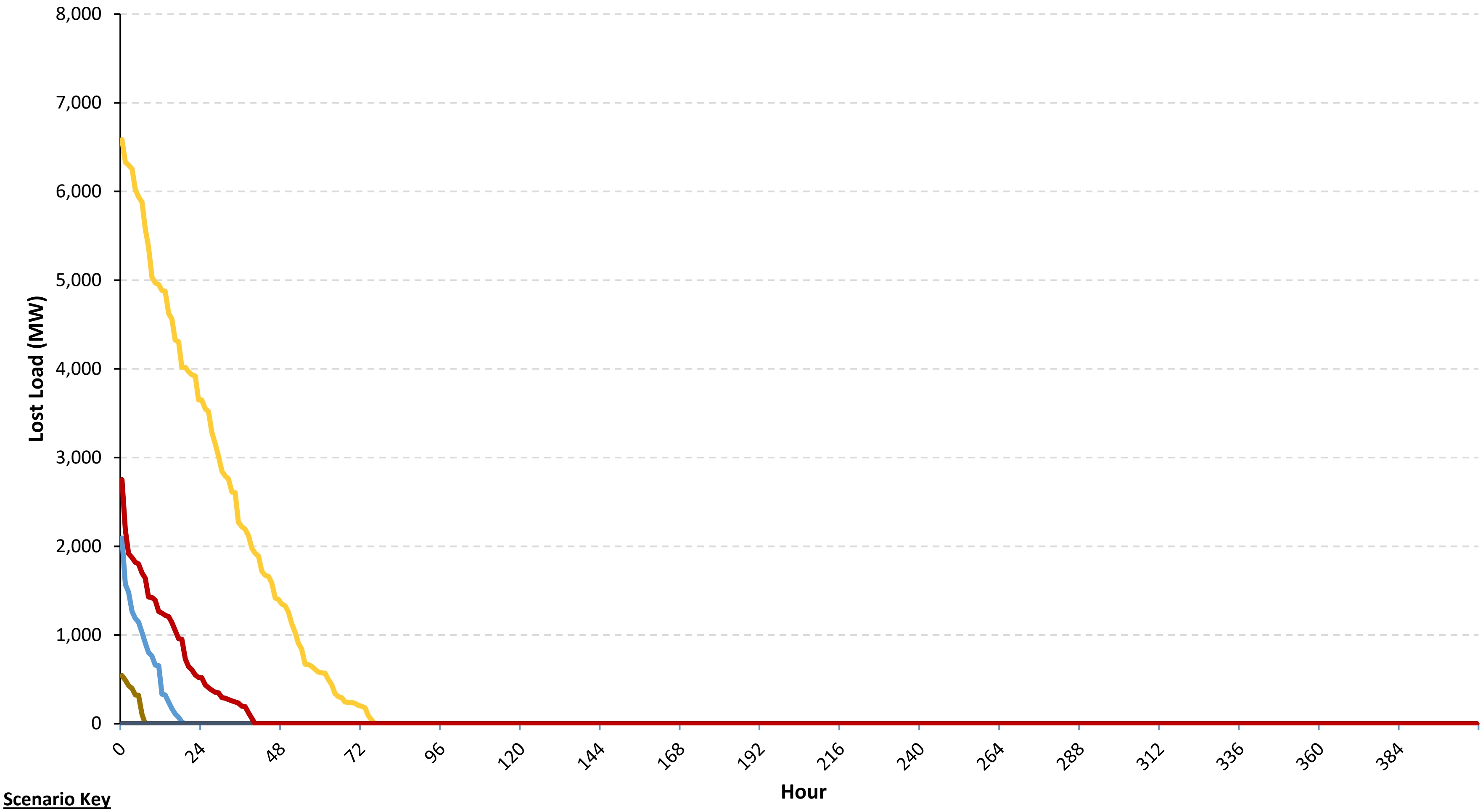


NYCA
Lost Load Duration (MWh)

Scenario 5: Initial Conditions + IM900 + PK + NGR



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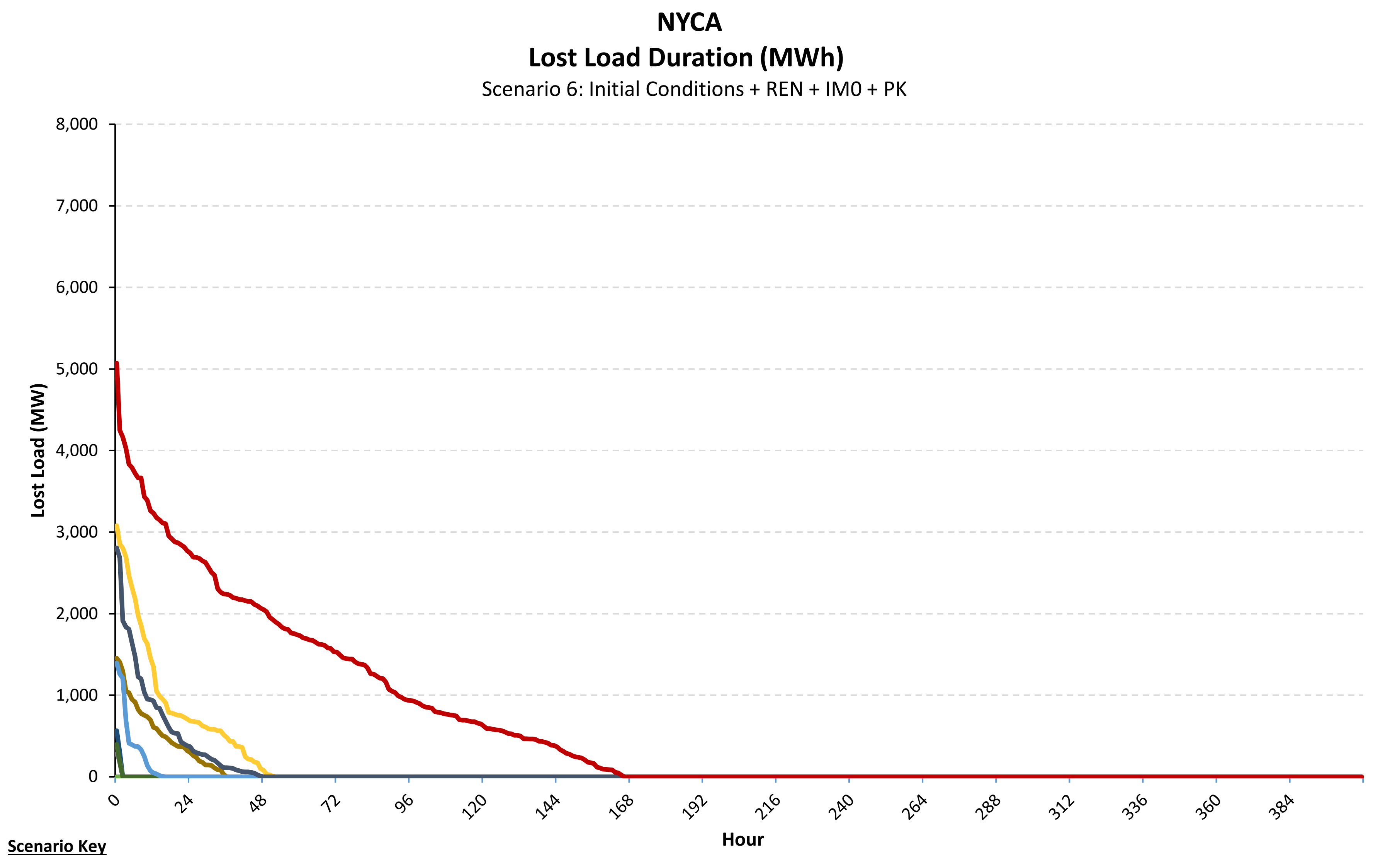

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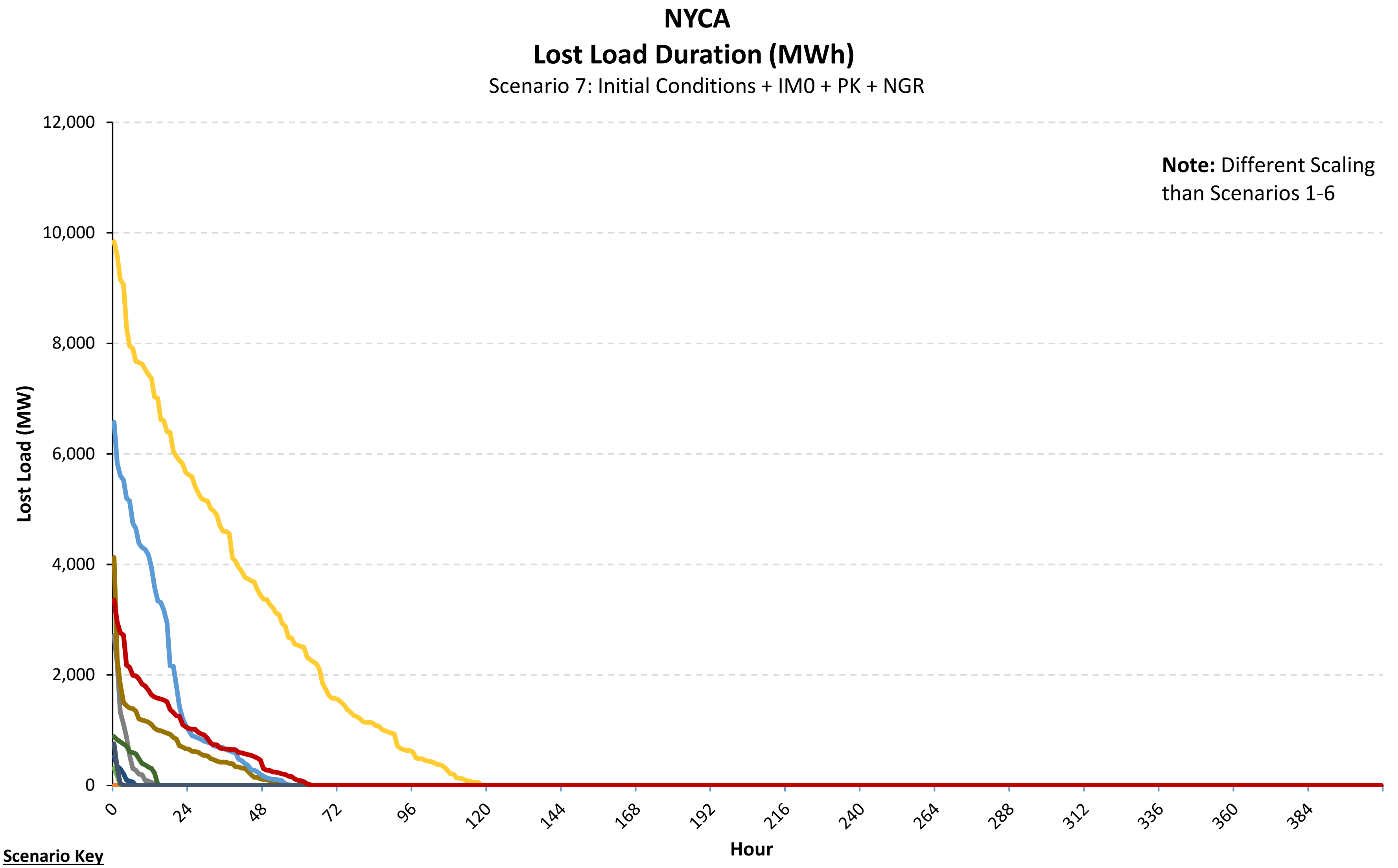

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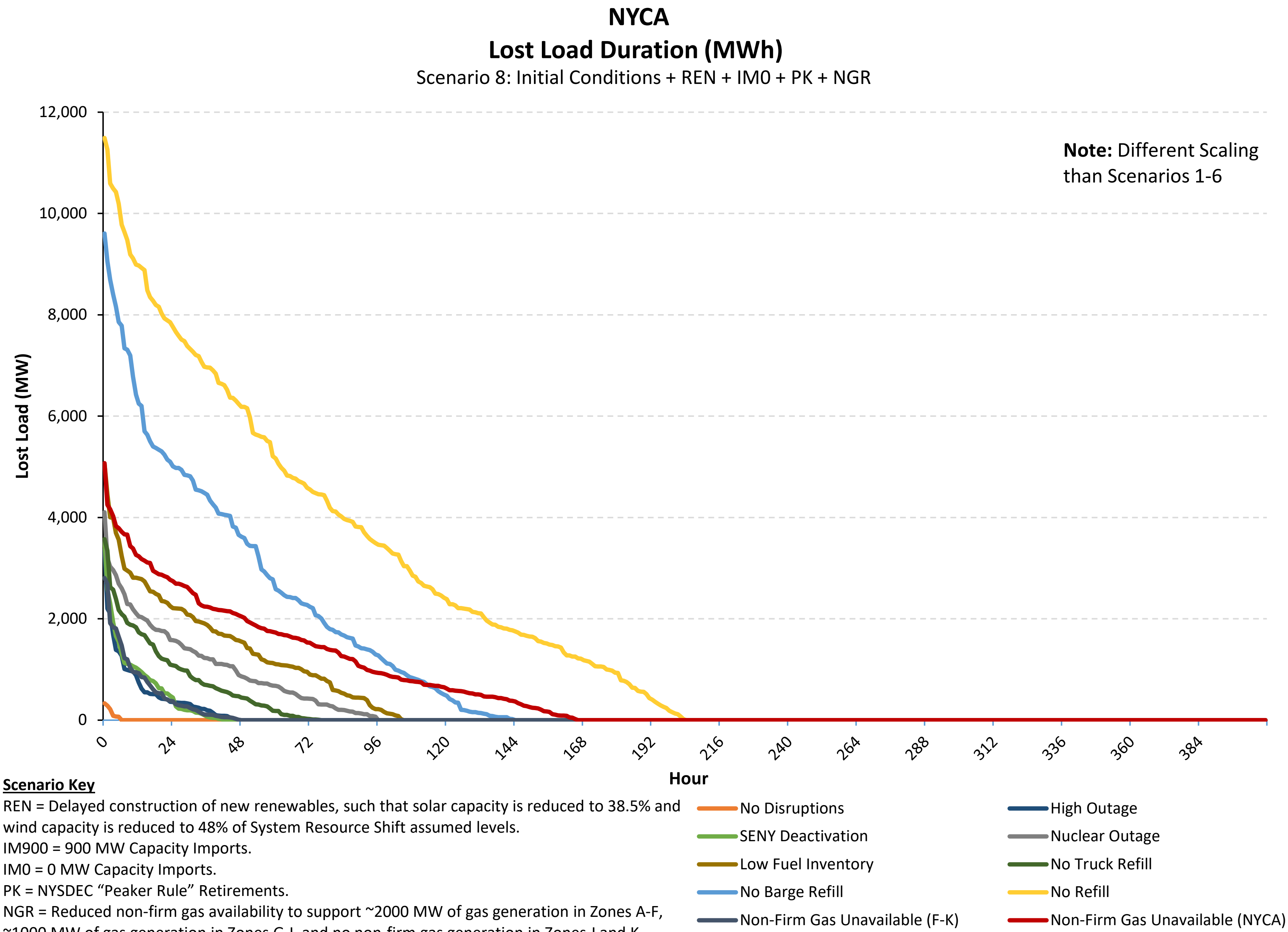

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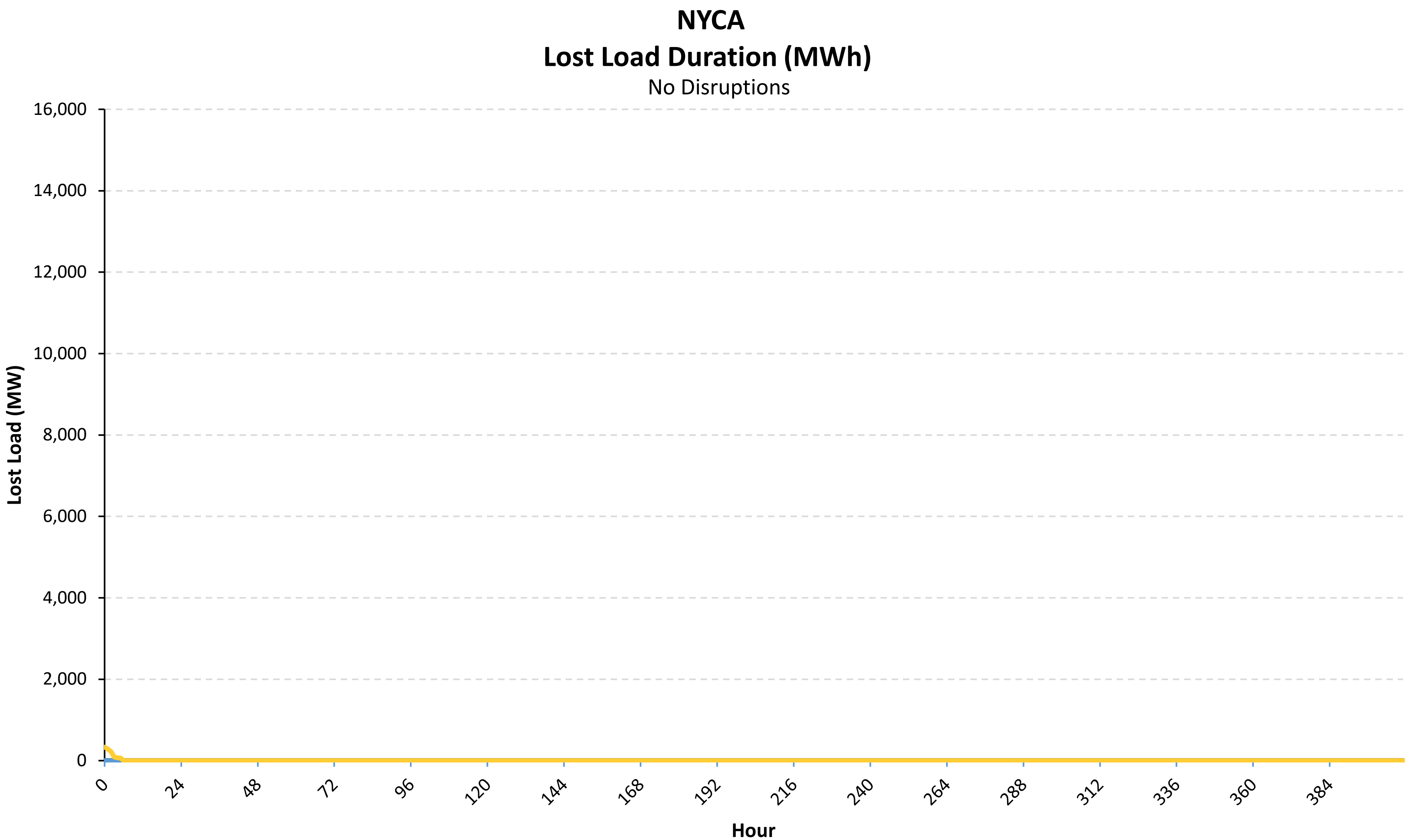

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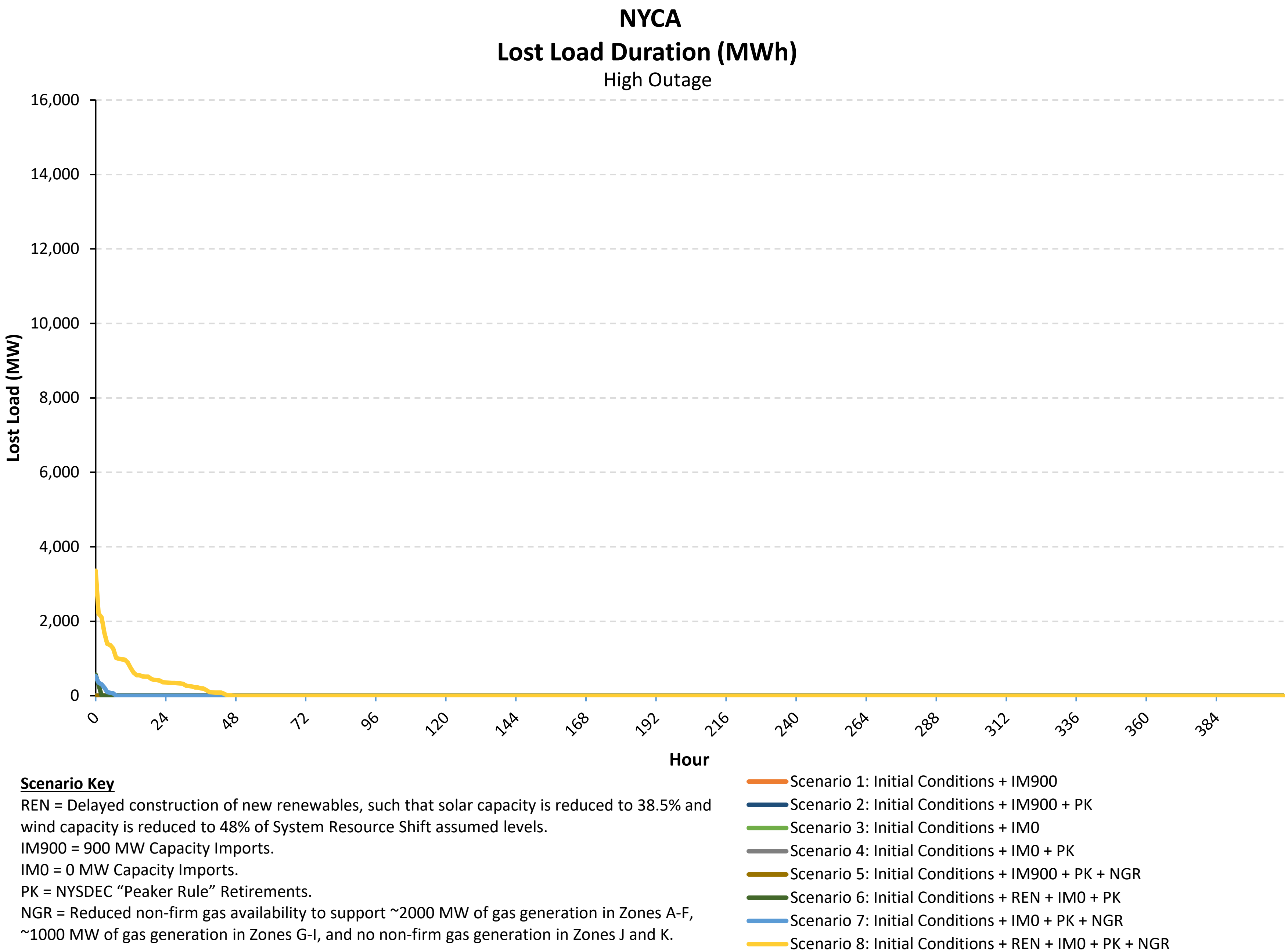
Scenario 1: Initial Conditions + IM900
Scenario 2: Initial Conditions + IM900 + PK
Scenario 3: Initial Conditions + IM0
Scenario 4: Initial Conditions + IM0 + PK
Scenario 5: Initial Conditions + IM900 + PK + NGR
Scenario 6: Initial Conditions + REN + IM0 + PK
Scenario 7: Initial Conditions + IM0 + PK + NGR
Scenario 8: Initial Conditions + REN + IM0 + PK + NGR



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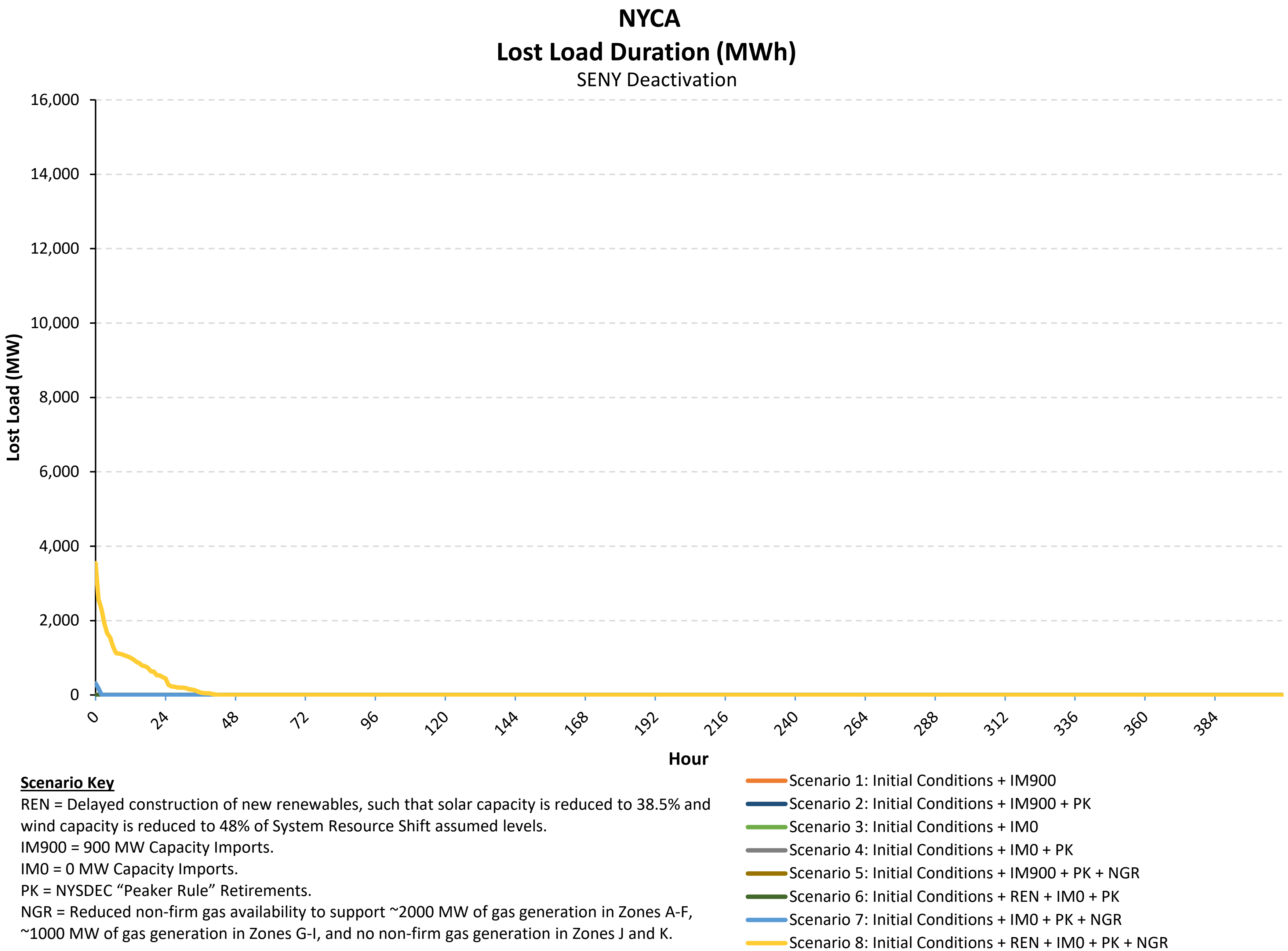

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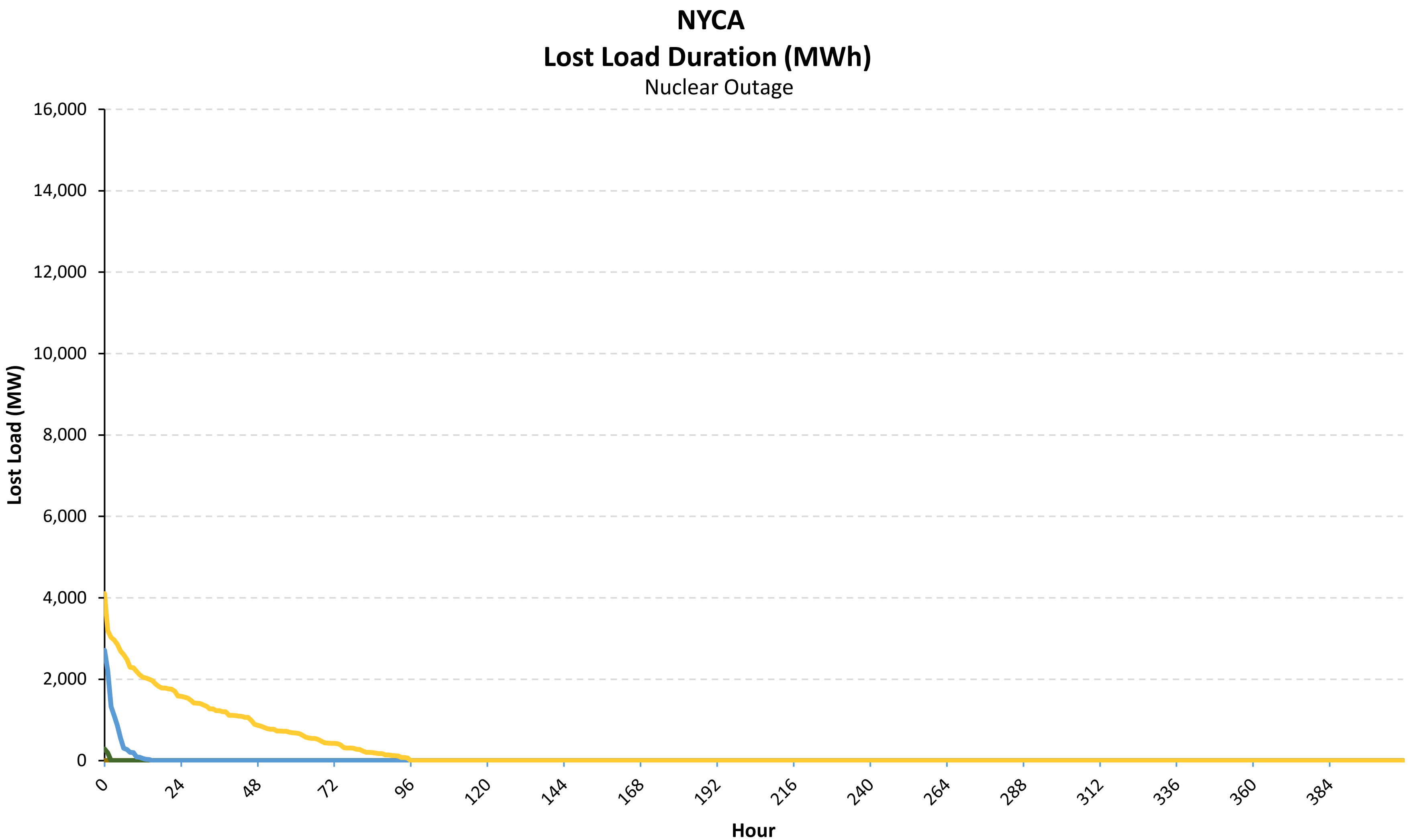

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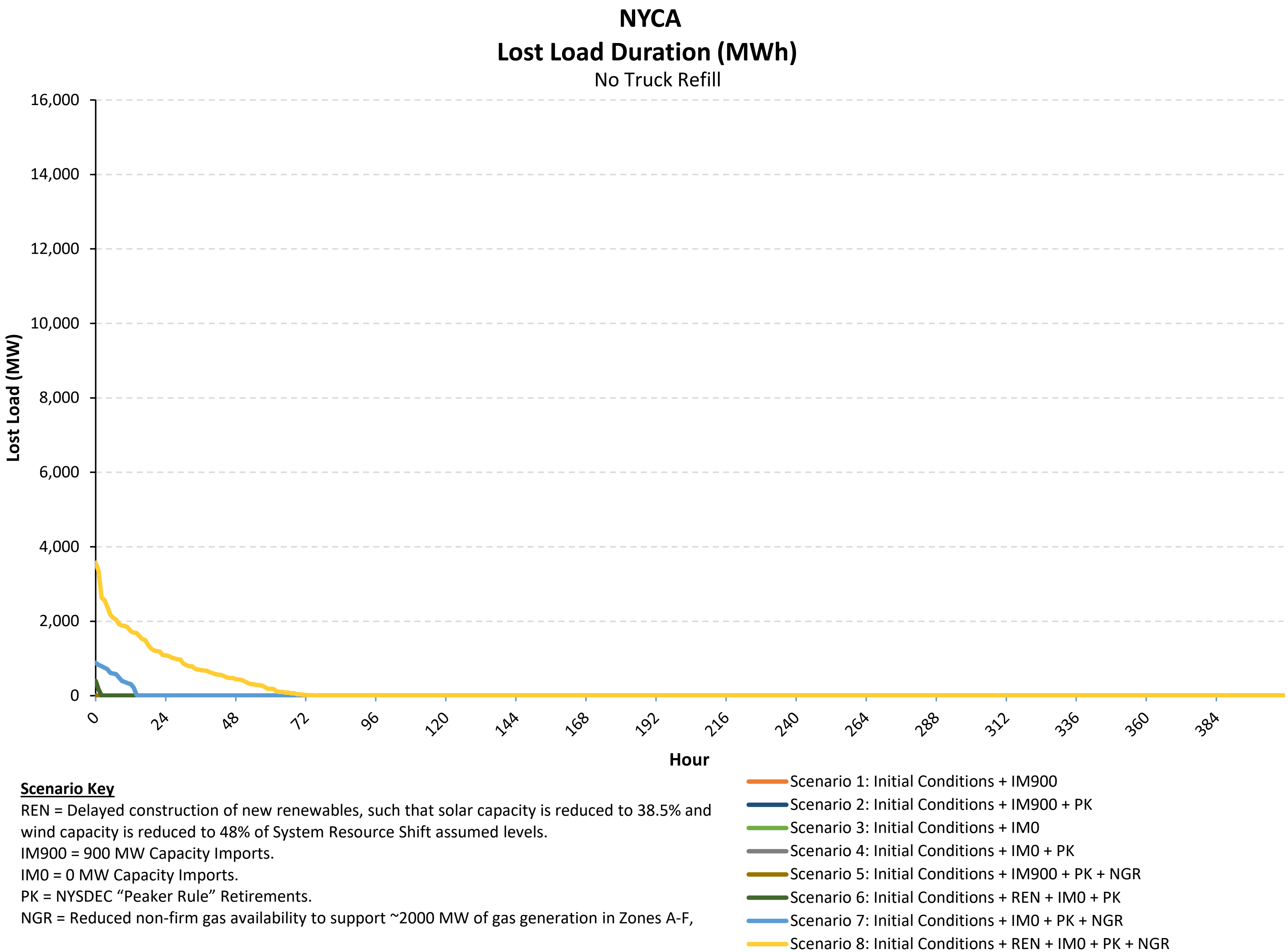

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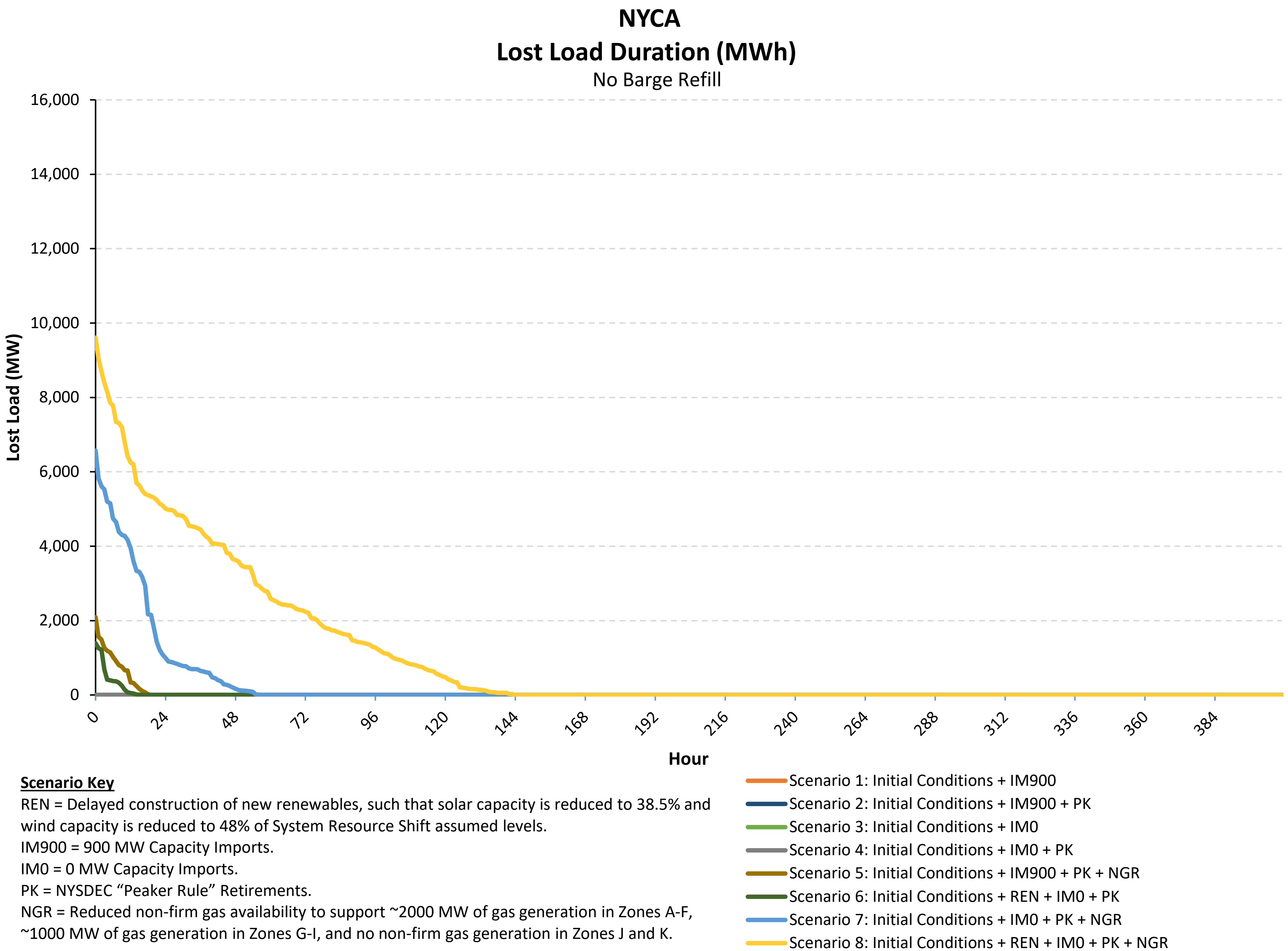

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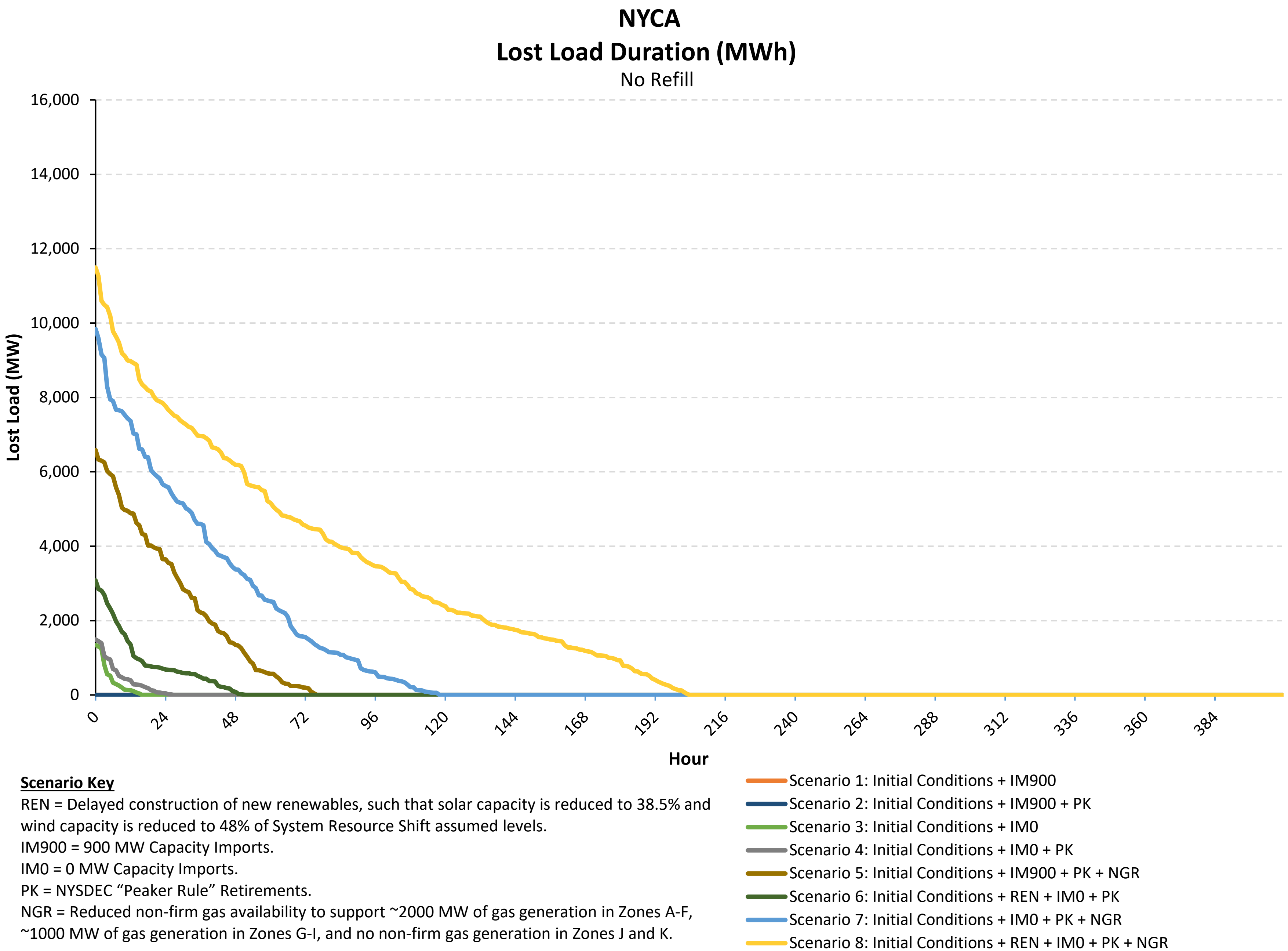

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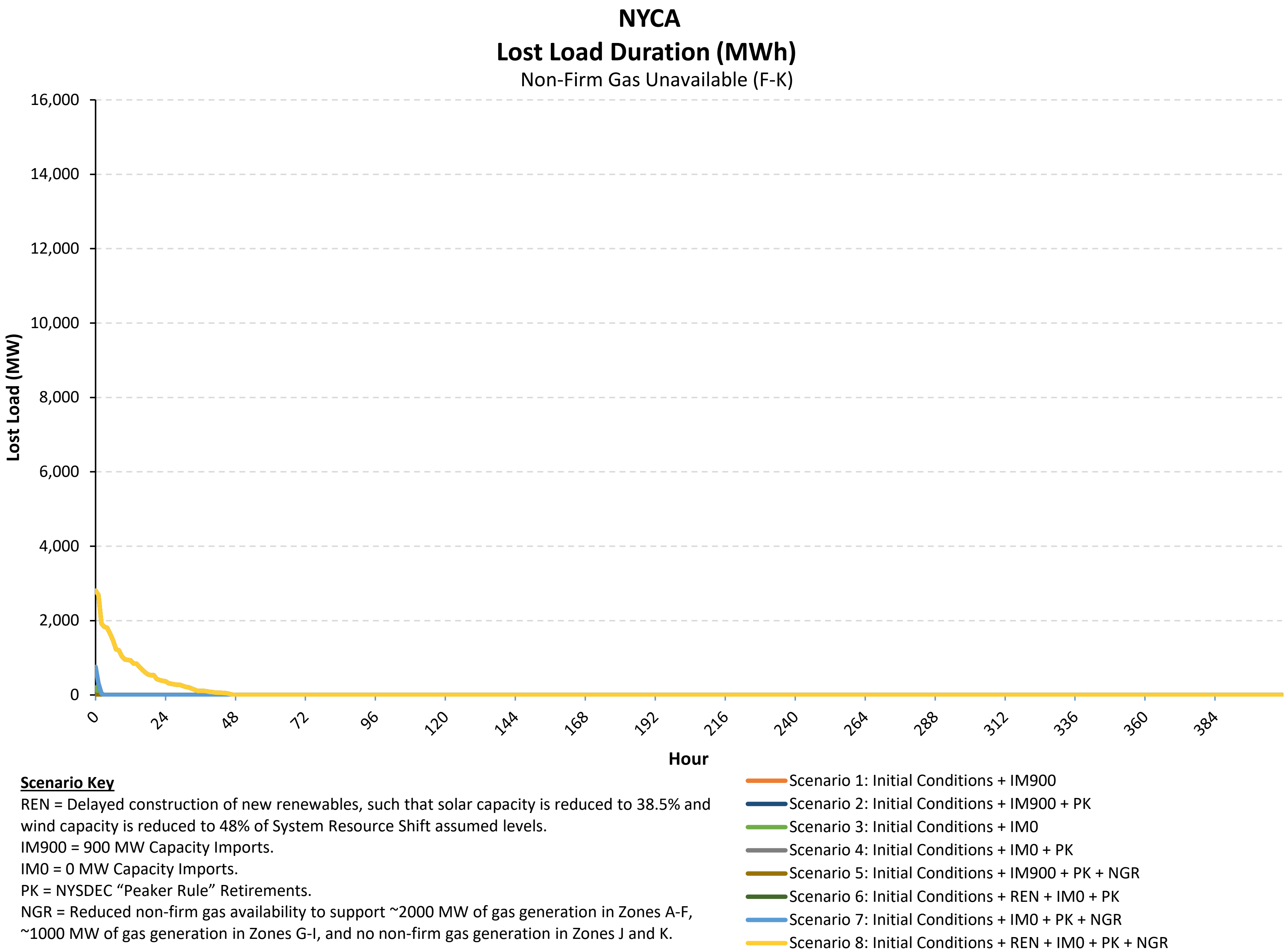

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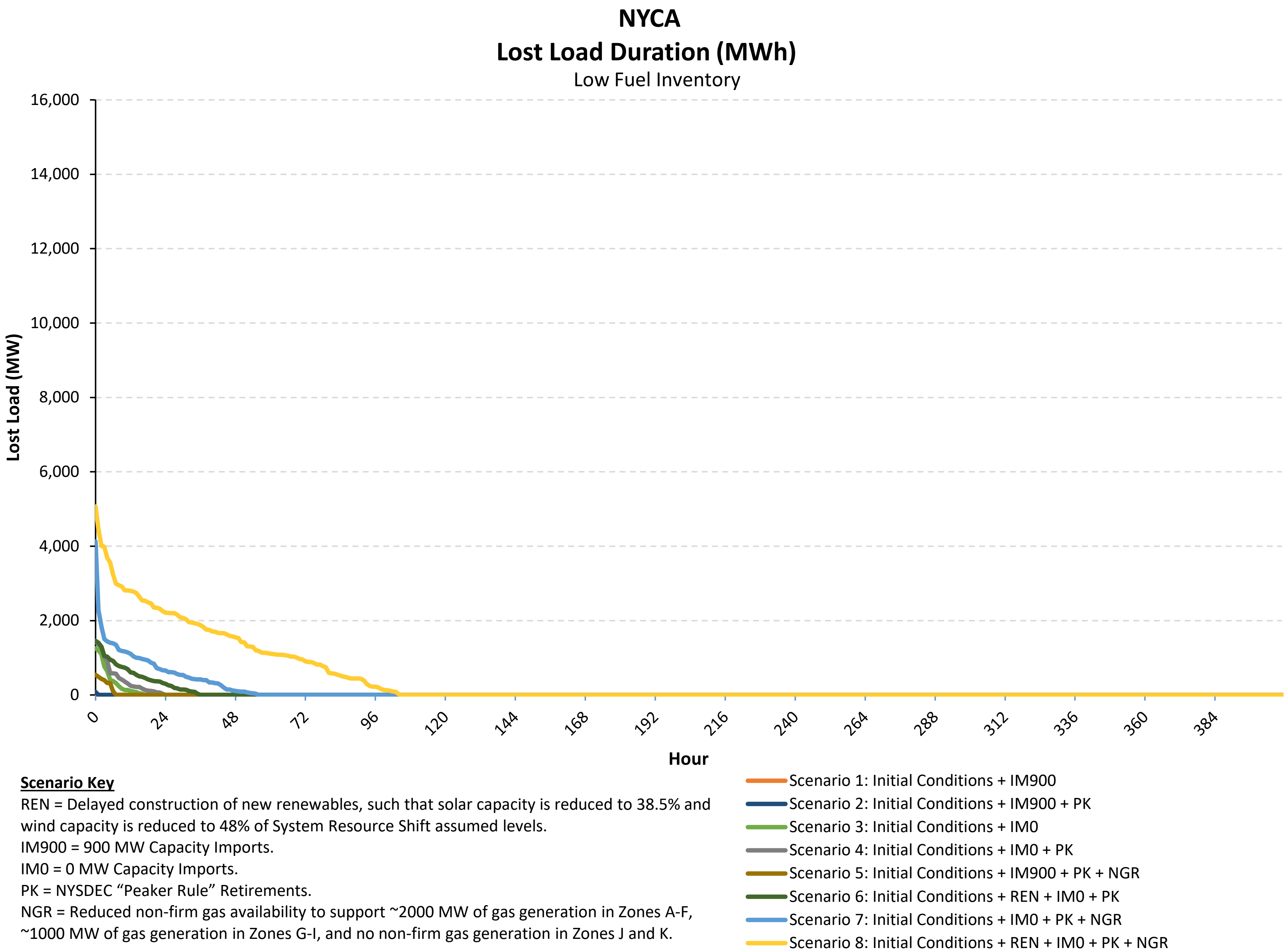

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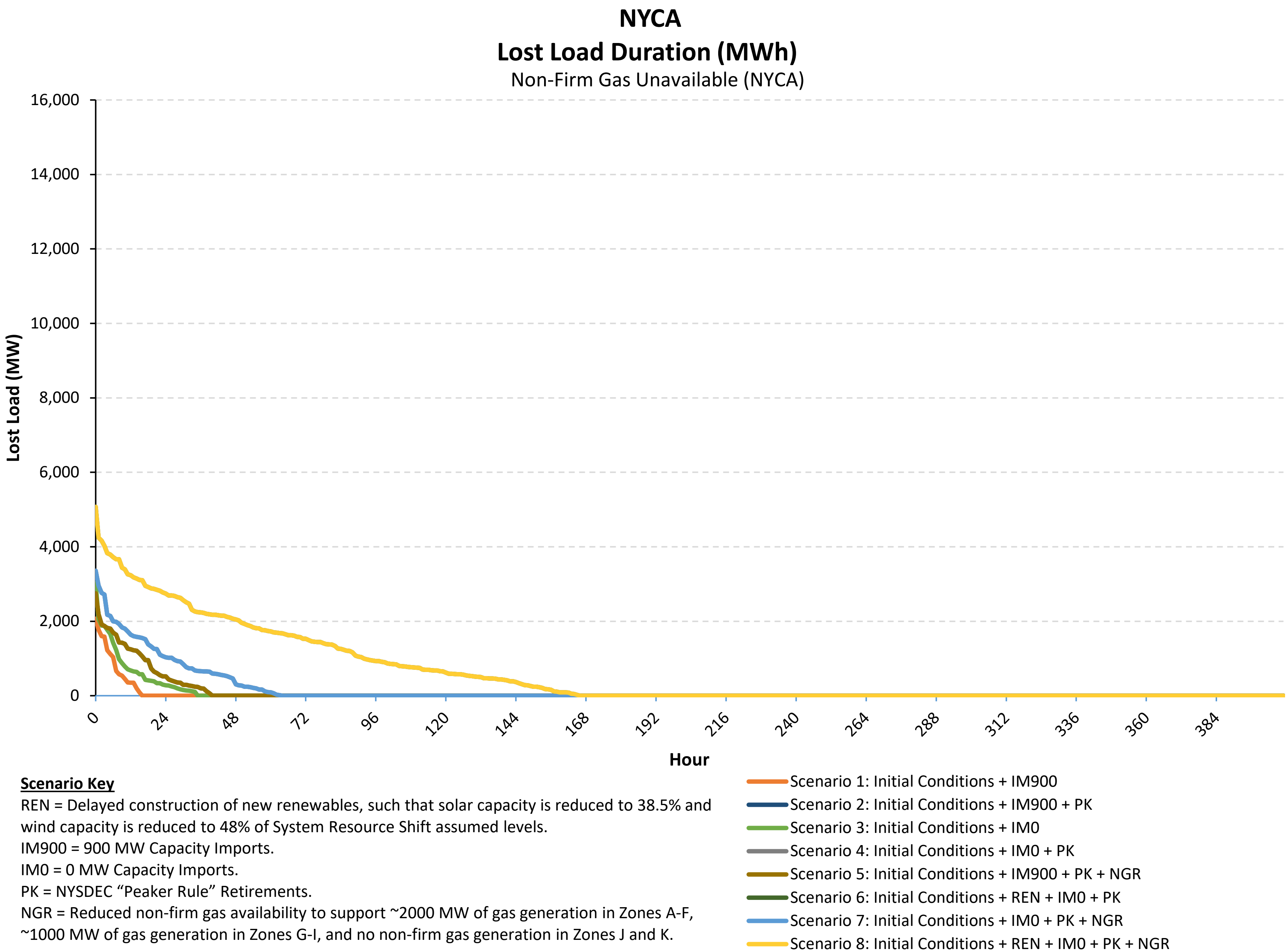

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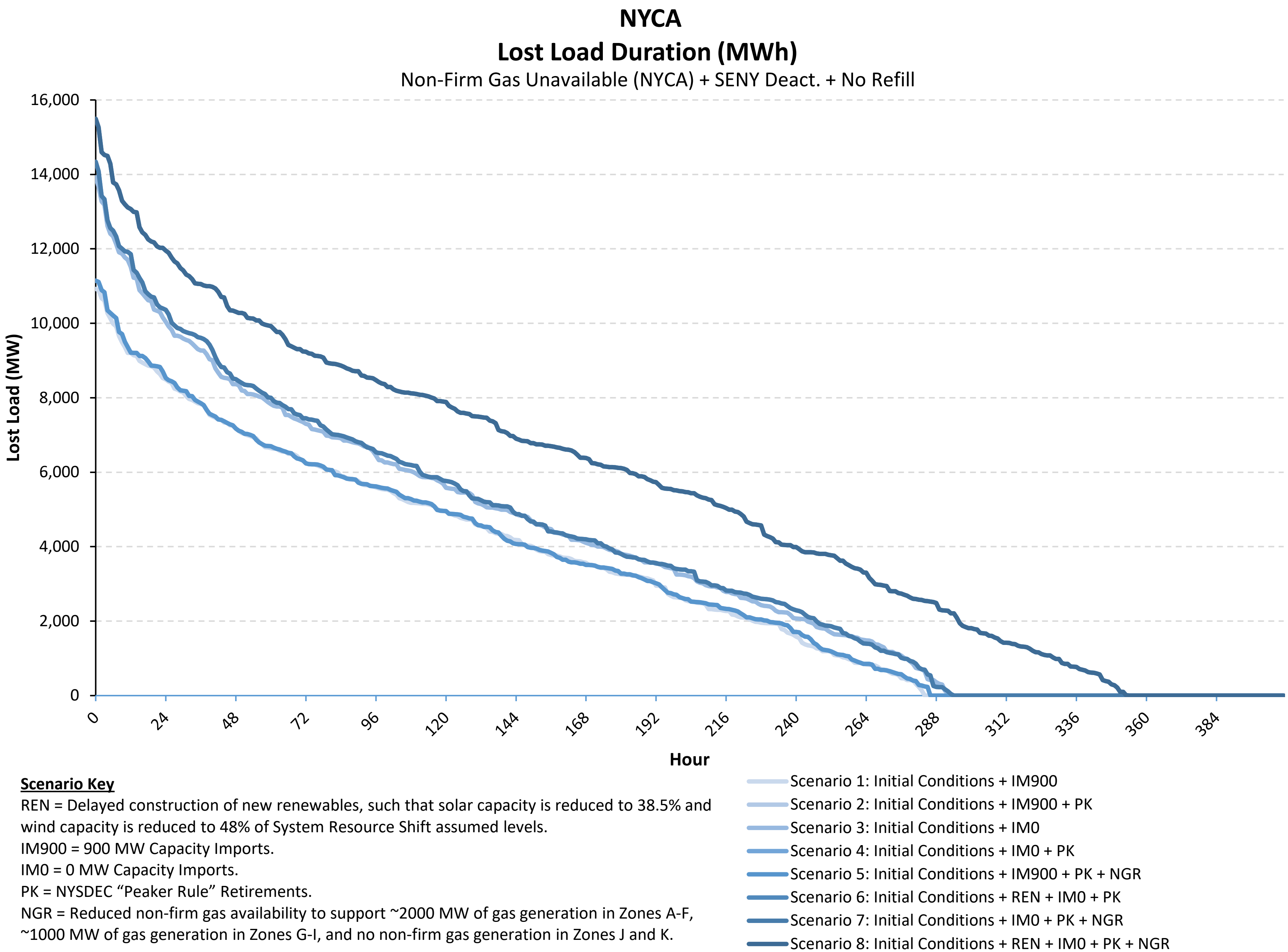

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E. Diagnostic Charts for All Cases