The Potential for Energy Storage to Repower or Replace Peaking Units in New York State

Contents

Executive Summary

On June 21, 2018, the Department of Public Service (DPS or Staff) and the New York State Energy Research and Development Authority (NYSERDA) filed the "New York State Energy Storage Roadmap and DPS/NYSERDA Staff Recommendations" (the Roadmap), which makes specific recommendations to encourage the development of energy storage in New York. Following the release of the Roadmap, the Public Service Commission (PSC or Commission) issued the Order Establishing Energy Storage Goal and Deployment Policy (Energy Storage Deployment Order) that established a statewide energy storage goal of 1,500 Megawatts (MW) by 2025 and up to 3,000 MW by 2030, and provided a suite of energy storage deployment policies and actions to support that goal.[1] The Energy Storage Deployment Order adopted several recommendations from the Roadmap, including the recommendation to analyze the operational and emissions data of conventional peaking units, defined as fossil-fuel generators with low utilization that typically operate during periods of high demand, to identify potential candidates for repowering or replacement with energy storage and/or clean resources.

Specifically, the Energy Storage Deployment Order called for Staff to consult with the New York Independent System Operator (NYISO), NYSERDA, the Department of Environmental Conservation (DEC), the Long Island Power Authority (LIPA), and Consolidated Edison Company of New York, Inc. (CECONY or Con Edison) to develop a methodology to be used in a study to analyze peaker operational and emission profiles on a unit-by-unit basis to determine which units are potential candidates for hybridization[2] or replacement. The Energy Storage Deployment Order directed Staff to file the study results produced by applying the methodology with the Commission by July 1, 2019.

As part of the unit-by-unit methodology called for by the Commission in the Energy Storage Deployment Order, this study examines two potential paths for peaking unit repowering or replacement. First, the study examines the potential to fully replace the historical output of peaking units with energy storage or energy storage paired with solar. Second, the study examines the ability of energy storage or energy storage paired with solar photovoltaic (solar or solar PV) to bring peaking facilities potentially impacted by the DEC's proposed regulations concerning Ozone Season Nitrogen Oxide (NO_x) Emission Limits for Simple Cycle and Regenerative Combustion Turbines (DEC's proposed NO_x rule) into compliance.[3] Approximately 4,500 MW of units are potentially subject to the DEC's proposed NO_x rule, although certain units installed after 1990 may not be impacted as they already have emission controls onsite. A majority of these units are traditional peaking units that operate less than ten percent of the time

---

[1] Case 18-E-0130, In the Matter of Energy Storage Deployment Program, Order Establishing Energy Storage Goal and Deployment Policy (Energy Storage Deployment Order) (issued December 13, 2018).

[2] For this analysis, the term "hybridization" refers to the installation of energy storage at an existing conventional unit's site where it is assumed to charge from the grid and discharge to displace the generation of those conventional units.

[3] See Proposed Part 227-3 Express Terms. Available at: http://www.dec.ny.gov/regulations/116185.html.

on an annual basis. For the purposes of this study, all units under the proposed NO_x rule are referred to as "peakers" regardless of their actual capacity utilization.

The analysis relies on historical 2013 hourly operational and emissions data for the approximately 4,500 MW of affected peaking units across the state (almost entirely concentrated in New York City, Long Island, and the Lower Hudson Valley) to examine the technical feasibility of energy storage or energy storage paired with solar providing equivalent historical generation of the peaking units. Peaker operational and emissions data from 2013 was chosen because this reflects the peak NYISO demand year, and the correspondingly high levels of peaker operation which occurred in July 2013.[4] This served as a proxy for representing peak-level system operations, although theoretical peak system operations may impose incremental needs beyond those of 2013. The study did not consider system changes after 2013 that may impact how conventional peaking units and energy storage resources operate in the future, such as retirements of existing units, changes in the overall levels and patterns of demand, new transmission solutions, and/or the addition of more intermittent, renewable energy.

Overall, at least 275 MW of peaking units, or around six percent of the total rated capacity of the fleet, are found to be potential candidates for replacement with 6-hour energy storage sized to the maximum 2013 output of each peaking unit. This number increases to over 500 MW when using 8-hour duration storage. Longer duration storage is considered in this study as current cost decline trajectories could result in long duration storage becoming viable over the compliance timeframes laid out in the DEC NO_x rule. When considering the ability of storage to hybridize peaking units to bring them into compliance with the daily NOx limit, standalone 4-hour storage is shown to bring 864 MW of peaking units into compliance.

The study also considers pairing a limited amount of solar with energy storage to replace or hybridize peaking units in order to bring their emissions into compliance with the DEC's proposed NO_x rule. Pairing solar with storage could result in 1,804 MW of peaking units being candidates for replacement or hybridization with 6-hour energy storage. This finding suggests that there is an opportunity to consider replacing or hybridizing a substantial portion of the peaking units subject to DEC's proposed NOX rule with a fleet of storage resources paired with solar. Such an outcome could deliver significant environmental benefits, advance the state's carbon reduction and clean energy goals, as well as benefit historically disadvantaged populations and communities such as environmental justice areas.

It is important to note that the unit-by-unit study did not examine energy storage charging constraints associated with multiple concurrent peaking unit replacements. Instead, differences in NYISO zonal and nodal energy prices were used as a proxy, with higher price differences

[4] See The New York ISO Annual Grid & Markets Report, Reliability and a Greener Grid: Power Trends 2019 (Power Trends 2019). Available at: https://www.nyiso.com/documents/20142/2223020/2019-Power-Trends-Report.pdf/0e8d65ee-820c-a718-452c-6c59b2d4818b.

reflecting potential charging constraints. It is possible that not all identified energy storage potential may be realized in every load area, particularly in certain constrained areas.

*Table E1: Total nameplate capacity (MW) of peaking units that can potentially be **fully replaced with storage** to meet the 2025 NOx limits at 100% sizing to each unit's 2013 peak generation*

Energy Storage Unit Hours of Operation				
	NYISO Zone	**4**	**6**	**8**
Standalone Energy Storage	Zone K	16	122	227
	Zone J	20	107	236
	Rest of State	47	47	47
	Total	**83**	**275**	**509**
Energy Storage Paired with Solar	Zone K	32	122	227
	Zone J	73	132	288
	Rest of State	47	47	47
	Total	**152**	**300**	**562**

*Table E2: Total nameplate capacity (MW) of peaking units that can potentially be **hybridized with storage** to meet the 2025 NOx limits at 100% sizing to each unit's 2013 peak generation*

		Energy Storage Unit Hours of Operation		
	NYISO Zone	**4**	**6**	**8**
Standalone Energy Storage	Zone K	743	883	883
	Zone J	74	195	477
	Rest of State	47	47	47
	Total	**864**	**1,125**	**1,407**
Energy Storage Paired with Solar	Zone K	876	1,015	1,129
	Zone J	627	742	1,135
	Rest of State	47	47	88
	Total	**1,550**	**1,804**	**2,352**

Energy storage or a combination of energy storage and solar is found to contribute towards meeting NO_x limits for a large number of units, although the minimum size storage required to meet the NO_x requirements can vary between simple-cycle and regenerative combustion turbine (SCCT) units of the same facility. A facility-wide strategy to meet the NO_x limits should therefore consider a combination of different compliance options across these types of units. Facility-wide compliance strategies are not examined in this study, and only potential compliance on a unit by unit basis was evaluated. Further, new peaking units (i.e., those built after 1990) generally have low average NOx rates, and may choose different compliance strategies than older, legacy units that generally have higher average NO_x rates.

Separate from this study, the NYISO analyzed the potential electric system reliability impacts that could result from the DEC's proposed NO_x rule and incorporated the results in its draft 2019-2028

Comprehensive Reliability Plan (CRP), which the NYISO expects to finalize by July 2019. The peaker scenario analysis identifies reliability issues that could arise if all impacted generators were to deactivate without replacement, and describes the nature of those reliability issues as guidance for market participants to proactively consider possible market-based solutions to reliability needs.[5] The NYISO projects that approximately 3,300 MW of peakers may be impacted by the DEC's proposed NO_x rule, as opposed to the full 4,500 MW of SCCTs in New York. This discrepancy is due to additional details considered within the NYISO analysis, such as onsite emission controls and more recent emission rate data not available for this study. The NYISO's analysis reveals that deficiencies would arise on the bulk and local power systems if all the impacted generators were to be deactivated without replacement solutions. Any solution or combination of solutions to the potential deficiencies would need to address the peak MW deficiency, as well as the total MW-hour (MWh) deficiency. The deficiencies could be addressed by various combinations of solutions, including generation, transmission, and demand-side measures.

Importantly, while this study considers the CRP "peaker" scenario assessment performed by the NYISO, Con Edison and LIPA, a detailed reliability analysis including charging requirements was not performed for this report. Comprehensive studies by the NYISO, Con Edison, and LIPA will be needed to understand the full reliability impacts of specific unit replacements, especially as loads and resources change as a result of greater electrification of transportation and buildings, and higher penetrations of renewables.

[5] The peaker scenario analysis is provided for information purposes to policymakers and market participants, and will not result in the NYISO identifying additional reliability needs this year. The NYISO will continue to monitor the DEC rulemaking process and will further consider any implications to system reliability in the 2020 Reliability Needs Assessment.

1 Introduction

Energy storage technologies offer New York numerous benefits and may serve many critical roles in achieving the State's clean energy goals. Under the Commission's Reforming the Energy Vision (REV) proceeding, New York has been transforming its electricity system into one that is cleaner and smarter, as well as more resilient and affordable. Per the Climate Leadership & Community Protection Act, legislation that passed both Houses in June 2019 and is awaiting the Governor's signature, by 2030, 70 percent of the electricity consumed in New York will come from renewable energy sources.[6] As New York's electric grid becomes smarter, more decentralized and cleaner, energy storage will be flexibly deployed to store and dispatch energy when and where it is most needed. As greater levels of intermittent renewable energy are brought online, integration solutions such as energy storage can help minimize curtailment and ensure that clean generation is used to meet periods of peak electric demand. Energy storage will also allow New York to meet its peak power needs without solely relying on the oldest and dirtiest peak generating plants, many of which lay mostly idle and are approaching the end of their useful lives.

This report presents and discusses the results of the unit-by-unit analysis including:

1. The MWs of peaking units that could potentially be replaced or hybridized with energy storage at varying durations;
2. An operational assessment looking at the equivalent level of energy storage, with and without solar, that could provide the same level of historical generation as the existing peaker units;
3. The emission reductions associated with peaker replacement.

Currently, there are approximately 4,500 MW of active fossil-fired SCCTs across New York, almost entirely concentrated in New York City, Long Island, and the Lower Hudson Valley. Many of these units have low utilization (generating electricity less than five or ten percent of the year), are approaching an average of 50 years of age and are generally used for meeting periods of high electric demand or for reliability purposes, providing operating reserves.[7] These units, referred to as "peakers", generally provide capacity to meet NYISO locational and system capacity requirements, operating reserves, and other, more local (i.e., utility-level) reliability-based services such as voltage support and system restoration.[8] Many of these peakers are dual-fuel and may be required to burn oil or kerosene in the winter due to reliability rules and/or fuel constraint concerns to relieve demand on the natural gas system.

[6] See the New York state Climate Leadership & Community Protection Act, Senate Bill S6599. Available at: https://www.nysenate.gov/legislation/bills/2019/s6599.

[7] The majority of these units are traditional peaking units that operate less than ten percent of the time on an annual basis, but there are some that operate more. For purposes of this study, all of the units under the DEC proposed NOx rule are referred to as "peakers".

[8] Contingency reserves are required to meet uninterrupted electric service if major transmission or distribution lines or generating assets are unavailable due to unplanned outages.

The DEC's proposed NOx rule lowers the allowable emissions from all SCCTs during the ozone season and may impact the availability of many of these peaker units. The proposed rule applies facility-level SCCT emission limits during the ozone season from May 1 through October 31 of each calendar year, beginning in 2023 and increasing in stringency in 2025.

Consistent with New York's overarching effort to deploy clean energy technologies, DEC's proposal includes compliance options allowing impacted facilities to use energy storage or renewable energy resources located at the same substation or within a half mile radius of the facility to assist in meeting the proposed regulations. This proposed compliance option imposes daily average emission limits on a pounds of NOx per MWh basis, beginning at 3 lb/MWh by 2023 and lowered to 1.5 lb/MWh for gaseous fuels, and 2.0 lb/MWh for liquid fuels such as distillate oil by 2025. The electric output of the energy storage or renewable energy resources that is delivered to the grid within this half mile radius is included in the total MWh used to calculate compliance with the pound per MWh daily emission limits. The proposed rule allows the NYISO or a local transmission/distribution owner to select generators to continue operating in the short term to maintain the reliability of the bulk and local transmission systems while long-term solutions are being developed.

As part of the unit-by-unit methodology required in the Energy Storage Deployment Order, this study examines both the full replacement potential of peaking units as well as the potential for energy storage and energy storage paired with solar to bring peaking facilities potentially impacted by DEC's proposed rule into compliance. This study does not include power flow modeling or a full analysis of local reliability requirements.

2 Study Scope

Consistent with the Energy Storage Deployment Order, the goal of this study is to complete an initial analysis of how many MW of peaking units could be replaced or hybridized with energy storage and clean resources,[9] particularly with regard to those units impacted by the DEC's proposed NOx rule.[10] The analysis considers standalone energy storage as an option for hybridization or replacement of individual units, as well as paired solar and energy storage systems.

2.1 Detailed Study Scope

The potential clean resource mixes that may reliably replace existing peak generating units must be able to fulfill two requirements. First, the mix of resources must meet the technical requirements of providing equivalent generation to the existing peaker during periods of need, thereby proving the ability to displace the peakers' generation and emissions. Second, the mix of

[9] "Clean" resources are defined as solar PV in this study.
[10] The list of the individual peaking units included in this study can be found in Appendix A.

resources must be able to satisfy Con Edison's and LIPA's inter-day and intra-day contingency planning requirements and NYISO's comprehensive reliability planning requirements. This study analyzes the first requirement, while future studies related to specific facility or portfolio plans should consider the second. In the Energy Storage Deployment Order, the Commission indicated the need for a Peaking Unit Contingency Plan to consider and report on portfolios of alternatives that could be deployed in the event that the peaking units are no longer available. As discussed in the Energy Storage Deployment Order, Staff expects that the Commission will institute a proceeding in the near future, to examine the broad reliability impacts of the proposed DEC regulations.

This study's analysis relies on historical 2013 hourly operational and emissions data for peaking units across the state to examine the technical feasibility of providing generation equivalent to that of the existing unit during all periods of the year. Peaker operational and emissions data from 2013 was used because the record peak demand in the New York Control Area (NYCA), and correspondingly high levels of peaker operation, occurred in July 2013.[11] Although the unit level operational profiles vary year to year, selecting the peak load year conservatively accounts for this variability on a fleetwide basis. The study did not consider system changes after 2013 that may impact how traditional peaking units and storage resources operate in the future such as retirements of existing units, changes in the overall levels and patterns of demand, new transmission solutions, and/or the addition of more intermittent, renewable energy.

This study is not a full reliability analysis and it should not be construed as such. Further analysis of each peaker's NO_x compliance plan will be required through the NYISO's Reliability Planning Process and Interconnection processes.[12]

2.2 Study Caveats

The following caveats and limitations on the scope of this analysis are important to note:

- **Annual Variability:** Historical peaker unit operational data from 2013 is used to examine the technical feasibility of hybridization and replacement. Due to year to year variability in unit and facility operations, different historical periods may result in changes in the total number of MW and specific units identified as potential candidates for replacement and/or hybridization. The changes in the total number of MW is expected to be small however, and 2013 (NYISO's peak load year) was selected to account for this variability. While this study examined historical energy data from 2013 to determine how storage resources could have participated, historical data may not be an accurate predictor of future use. The system changes between 2013 and 2023/2025 are likely to impact how traditional peaking units and storage resources operate in the future.[13]

[11] Power Trends 2019.
[12] See the NYISO's Comprehensive System Planning Process details, available at: https://www.nyiso.com/planning.
[13] System changes by 2023/2025 will include, but are not limited to, the retirement of Indian Point and the termination of the Con Edison-PSEG wheel.

- **Reserve Requirements:** The study did not analyze peaking unit contributions to reserve requirements in 2013, nor did it consider the potential ability of storage and solar to provide those same requirements. However, insofar as the peaking unit was called on to generate and perform under a reserve call, the operational profile of the call(s) would be included in this analysis.
- **Owner or Operator Business Decisions**: The candidates identified in this report represent the peaking units most suited for storage replacement or hybridization based purely on an ex-post operational assessment. The report does not speak to the economics of using storage to replace or hybridize peakers, nor does it address reliability solutions for units that may be retired due to policy or economic drivers where energy storage is not found to be a suitable alternative replacement resource. Furthermore, units not identified as candidates for hybridization or replacement may still elect to rely on energy storage or a system of clean energy resources either for economic benefits alone or as a compliance option; for example, storage could offset a portion of generation, allowing units to operate up to the output that meets emissions limits but potentially resulting in lower available total MWs/MWhs from the peaker.
- **Power Flow Analysis:** While this study discusses the CRP "peaker" scenario performed by the NYISO, Con Edison and LIPA, a detailed reliability analysis including charging requirements was not performed. Comprehensive studies by the NYISO, Con Edison, and LIPA will be needed to understand the full reliability impacts of specific unit replacements, especially as loads and resources change with greater electrification of transport and buildings and higher penetrations of renewables.
- **Detailed Reliability Study:** Additionally, a study that considers the reliability contribution of storage and other resources over time is recommended. An example of how this type of analysis and study could be performed is provided in Appendix D.
- **Data Availability:** For many of the units, operation data is only reported from April through September.[14]
- **Optimization:** Energy storage resources are modeled using an optimization tool with perfect foresight of the timing and duration of historical peaker generation to screen for which units have an operational profile that storage could displace.
  - Storage dispatch is optimized to displace historical 2013 peaker unit dispatch.
- **Charging Constraints:** Charging constraints are imposed using historical zonal-nodal congestion pricing data as a proxy for any local charging constraints. A range of congestion thresholds from $10 to $1,000 price differentials between hourly generator and zonal Location-Based Marginal Prices (LBMPs) were modeled to explore the sensitivity of results to congestion charging constraints.
  - In cases where both solar and energy storage resources are available, the energy storage is not restricted to charging from solar only.

[14] Historically April 1 through September 30 represented the ozone season in New York; the proposed definition has shifted to May 1 through October 31.

- **Solar Potential:** Limited site-by-site analysis of land use potential for solar was performed. Interconnection limitations and potential system upgrade requirements were not considered.
- **Benefit-Cost Analysis:** A full and detailed lifecycle benefit-cost analysis of either replacement or hybridization was not performed due to lack of information and the timeframe of this analysis. Each facility and plant owner will conduct their own analysis weighing the costs and benefits of different environmental compliance paths and the options of replacement and hybridization.

3 Methodology

The analysis in this study was performed by Energy and Environmental Economics (E3)[15]. The unit-by-unit methodology deployed in this study first creates a database of hourly historical operations and emissions profiles for all peaker units in New York. This hourly data is input into E3's energy storage dispatch tool[16] which simulates optimal storage dispatch (either on a standalone or paired basis) in response to different prices signals and constraints. The resulting storage operational profiles are compared to the historical unit operation to determine whether storage is able to fully displace the peaker generation or if adding storage allows the unit to meet the proposed NO_x emissions limits. The table below summarizes the key inputs and assumptions used for this analysis. Detailed descriptions of the data sources and methodologies are provided in the following sections.

Table 1: Summary of Key Inputs and Assumptions

Input	Source & Method
Peaker Operations/Emissions	Continuous Emissions Monitoring Systems (CEMS)[17] 2013 Data for hourly output and emissions, cross-checked with United States Energy Information Administration (EIA) Form 923[18] facility data
Replacement	4, 6 and 8-hour storage (plus solar scenario) sized to 100, 125 and 150 percent of maximum 2013 output must replace all annual operations, charge and discharge determined by E3 storage dispatch tool
Hybridization	4, 6 and 8-hour storage (plus solar scenario) sized to 25, 50, 75, 100 percent of maximum 2013 output must average with peaker emissions to fall below 3 lb of NOx per MWh daily (to reflect 2023

[15] See www.ethree.com.
[16] This same tool was used to perform the use case analytics in the New York State Energy Storage Roadmap. More information on the tool can be found here: https://www.ethree.com/tools/restore-energy-storage-dispatch-model/.
[17] See United States Environmental Protection Agency Air Emission Measurement Center, Continuous Emission Monitoring Systems Information and Guidelines. Available at: https://www.epa.gov/emc/emc-continuous-emission-monitoring-systems.
[18] See United States Energy Information Administration, Form EIA-923 detailed data with previous form data (Form EIA-923). Available at: https://www.eia.gov/electricity/data/eia923/.

	limit) and 1.5 lb/MWh for gaseous fuels or 2.0 lb/MWh for liquid fuels (to reflect 2025 limit)
Solar Scenarios	Solar is added with energy storage to replace or hybridize peaker. For downstate peakers, 20 percent of the full technical rooftop potential within a half mile radius of each plant is assumed to be developable.[19] A flat 10 MW of solar is added for peakers not located in Lower Hudson Valley, New York City, and Long Island. The overlapping area of adjacent plants is allocated equally between the plants. Storage is assumed to be able to charge from grid and/or solar.
Charging Constraints	Screening for high congestion at generator node is used to limit the ability of storage to charge
Energy Pricing	Historical 2013 NYISO pricing data[20] (generator and zonal hourly LBMPs)
Energy Storage Assumptions	Optimized dispatch under perfect foresight with 85 percent roundtrip efficiency

3.1 Data Collection

The full list of peakers includes all existing SCCTs, equating to approximately 4,500 MW of total nameplate capacity. This list was assembled using NYISO generator data,[21] filtered to look at only SCCT units (in the NYISO data, the relevant technology types are "GT" and "JE" for jet engine). A database of unit-level 2013 operations and emissions for each peaker was created using CEMS data accessed through the EPA's Air Markets Program Data (AMPD) application.[22] This data includes unit-by-unit hourly generation, operating time and carbon (CO_2), sulfur dioxide (SO_2), and NO_x emissions. Indicators such as average and maximum start times, total starts and time between starts were developed from this dataset. As mentioned in Section 2.2, for a sub-set of units only partial year data – ozone season only – is available.[23] EIA Form 923 monthly power plant operations data was matched with the CEMS data at the facility level and used to verify the CEMS hourly unit operational data.

The database includes several units that ran at capacity factors well above ten percent for 2013—these high capacity factor units are not traditionally considered peaking facilities, but as SCCTs

[19] 20 percent is based on an estimate of a ratio between economic and total technical potential for rooftop and distributed solar in New York State.
[20] See NYISO Energy Market & Operational Data. Available at: https://www.nyiso.com/energy-market-operational-data.
[21] See NYISO 2019 Load & Capacity Data, Gold Book. Available at: https://www.nyiso.com/documents/20142/2226333/2019-Gold-Book-Final-Public.pdf/a3e8d99f-7164-2b24-e81d-b2c245f67904?t=1556215322968.
[22] See United States Environmental Protection Agency Air Markets Program Data. Available at: https://ampd.epa.gov/ampd/.
[23] About half of the units analyzed only report CEMS data during the 2013 ozone season. Ozone season here refers to May through September 2013. The definition of ozone season for DEC's proposed NOx regulation has changed to May to October.

they are subject to the DEC's NOx regulations and are therefore included in the analysis. Likewise, a number of units in the database were built more recently (i.e. post-1990) and have lower average NOx emissions rates relative to the units that are near or over 50 years of age. All units subject to the DEC's proposed regulation were included in the analysis, and no presumptions were made regarding the potential compliance pathways of individual units based on age, capacity factor, or any existing pollution controls.

Several peaking units did not have CEMS unit level data available and were therefore not analyzed. Several units also have mothballed or deactivated since 2013. These units are excluded from the results but are included in the full list of units in
Appendix A: List of Units Examined in this Study. The map below shows the locations of the peaking units in New York City and Long Island which were examined in this study.

Figure 1: Map of Downstate Peakers Analyzed[24]

The table below summarizes the overall 2013 fleet characteristics of the peaking units analyzed (note that NO_x, CO_2 and SO_2 emissions are weighted average emissions rates):

[24] Three plants located outside of Zones J and K - S A Carlson, Hillburn and Shoemaker- are not shown here but are included in the analysis.

Table 2. Peaking Units: Overall Characteristics Based on 2013 Data[25]

Zone	# of Units	Average Age	Total Nameplate Capacity (MW)	Avg Unit Size (MW)	Average CF (%)	Avg Hours per start	Avg Longest Start (hrs)[26]	Avg NOx Emissions (lb/MWh)	Avg CO2 Emissions (tons/MWh)
J	81	45	2169	23	5.3%	7	26	7	0.8
K	52	39	2172	41	7.8%	18	70	8	1.1
G	2	47	88	40	0.4%	3	8	6	1.0
A	1	18	47	45	52.3%	238	2108	1	0.7
Total	**136**	-	**4477**	-	-	-	-	-	-

Similarly, operational data**[27]** from the peaking units were as follows:

Table 3. Peaking Units: 2013 Operational Data

Zone	Summer Gen (MWh)	Summer NOx (lb)	Summer CO2 (tons)	Total Gen[28] (MWh)	Total NOx (lb)	Total CO2[29] (tons)
J	542,467	1,409,877	356,984	1,019,905	1,634,182	686,981
K	831,843	1,561,438	589,935	1,649,089	2,376,562	1,101,226
G	476	4,933	692	2,439	14,702	2,077
A	71,610	83,673	46,633	206,014	274,735	135,579
Total	**1,446,396**	**3,059,921**	**994,244**	**2,877,447**	**4,300,181**	**1,925,863**

The historical 2013 generation of the peaking units is shown below in aggregate as compared to the total nameplate capacity. While the units do not operate near capacity at any period in 2013, they were dispatched concurrently during a few scarcity periods, particularly in the summer months.

---

[25] 2013 is not necessarily a representative year from a meteorology perspective and the fleet characteristics may change year to year.

[26] The average longest start for the peaker fleet in 2013 is significantly higher than in the years analyzed for the Energy Storage Roadmap (2015-2017). 2013 is the NYISO's peak load year and reflective of high levels of peaker operation.

[27] To the extent possible, this was based on hourly data.

[28] For units that do not report winter data, totals were estimated using summer capacity factor.

[29] CO_2 & SO_2 values were estimated with the group average emission factor for units that do not report data

Figure 2: Timeseries of Fleet Operations

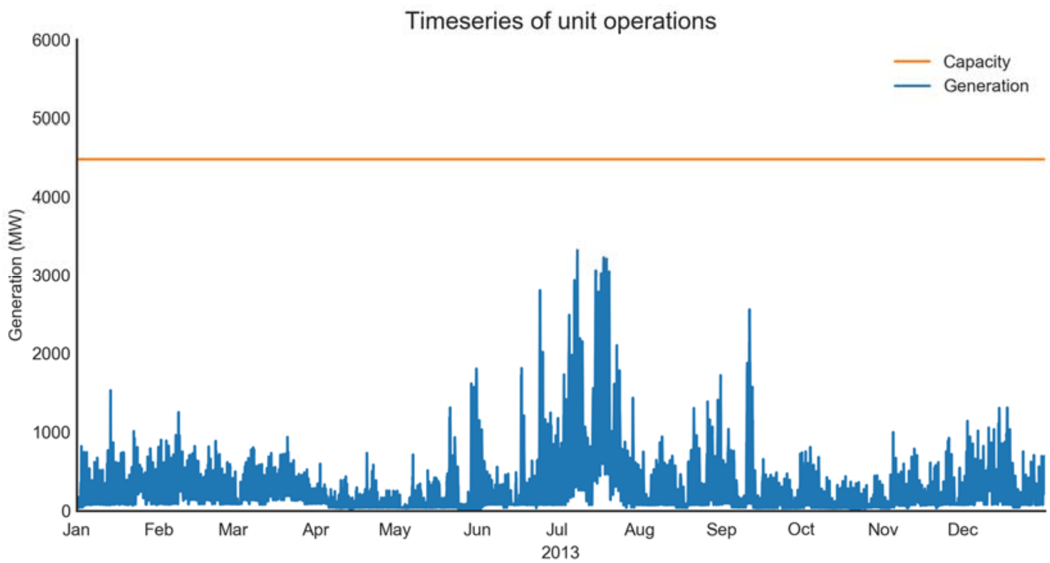
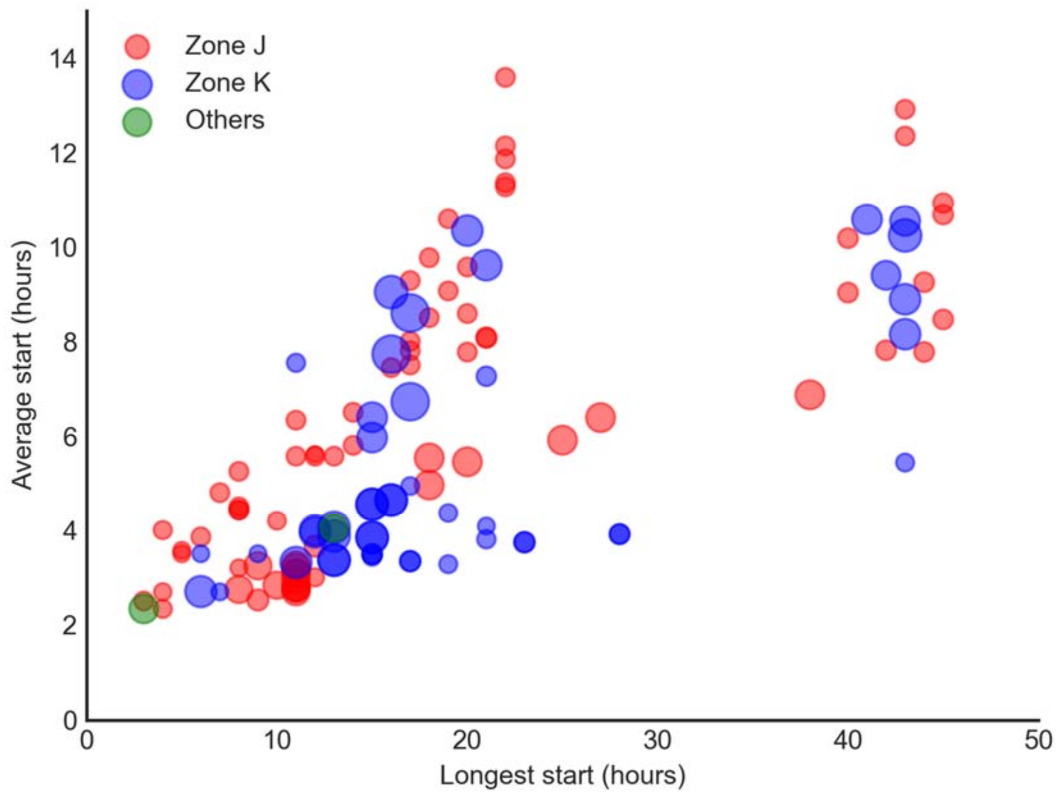


Figure 3 below illustrates Hours per Start and Longest Start of the peaking units in the database, using 2013 data where the size of the bubbles corresponds to the unit's size in MWs.

Figure 3: Hours per Start and Longest Start of the Peaking Units



The table below summarizes the NO_x emissions of the peaking units analyzed, including the average number of days in 2013 when the proposed DEC emissions limits would have been exceeded.[30] As noted above, all SCCTs subject to the DEC's proposed regulation and found to be noncompliant based on 2013 operations are included in the analysis even if the exceedance was for a single day or associated with a relatively small amount of generation. The age and NO_x emissions rates of individual units is shown in Appendix A.

[30] Calculated for ozone season data available (May through September). Data for October not available for all units.

Table 4. 2013 NOx Emissions

Zone	Summer NOx (lb)	Total NOx[31] (lb)	Avg Emissions (total lb/MWh)	Max Average Emissions (lb/MWh)	Avg Days of 3 lb/MWh Exceedance	Avg Days of 1.5 lb/MWh Exceedance
J	1,409,877	1,634,182	6.5	11.8	22	22
K	1,561,438	2,376,562	8.0	47.8	55	57
G	4,933	14,702	5.6	5.7	12	12
A	83,673	274,735	1.3	1.3	0	57
Total	**3,059,921**	**4,300,181**	-	-	-	-

The CEMS data was matched with NYISO zonal and generator price data to examine congestion. The price differential between zonal and individual generators is used as an indicator for congestion. If the generator price is higher than the zonal price by a certain stated amount, a charging constraint is assumed and the storage is prohibited from charging. Different congestion thresholds (i.e., price differentials) were examined to explore the sensitivity of the results to different levels of charging constraints.

3.2 Storage Replacement and Hybridization Analysis

E3's storage tool is used to simulate the optimal operation of different types of energy storage assets either on a standalone or paired with solar basis. The core "engine" of the tool uses a mixed integer linear programming (MILP) algorithm, which identifies the profit maximizing operation pattern for a storage asset given its size and performance characteristics, the revenue streams to which it has access, the market in which it is expected to operate, and the applicable expected market prices.

The modeling tool was used to explore the potential for hybridization and replacement on a unit by unit basis for the entire dataset of peakers described above in Section 3.1. The hourly unit operational data was converted into a dispatch stream to result in maximum potential peaker displacement by the storage subject to charging constraints due to congestion related to load pocket issues. The storage responds to the signal to dispatch during the historical operation of the unit with charging prohibited during times of congestion, defined by a differential between generator and zonal LBMP. Because the goal of the analysis was to model whether storage of different sizes and durations was capable of displacing the unit's operation, energy storage sizing assumptions are based off each unit's 2013 maximum generating output. However, the maximum output in one year may not reflect the full capacity of each unit. The maximum output in 2013 was therefore compared to its nameplate capacity and summer and winter Capacity Resource Interconnection Service (CRIS) or deliverability limit for each unit. Overall, summer CRIS

[31] For units that do not report winter data, totals were estimated using summer capacity factor

capacities are similar to the 2013 maximum outputs observed across the studied units. Nameplate capacities are on average 20 percent larger than the 2013 maximums, and winter CRIS capacities are around 40 percent larger across all of the units.

In order to capture the potential for higher capacity injections, storage sizing above the peak output was also considered. For replacement, the storage is sized to 100, 125 and 150 percent of the unit's 2013 maximum output MW with durations of 4, 6 and 8 hours.[32] For hybridization, the storage is sized to 25, 50, 75 and 100 percent of the unit's 2013 maximum output with durations of 4, 6 and 8 hours. These sizing options are meant to cover potential replacements or hybridizations of units while allowing site owners to maximize the use of existing interconnections and CRIS. For example, many units maximum output was significantly below the summer or winter CRIS of the unit, meaning that storage sized to 100 percent of 2013 maximum output would be sized below available CRIS. In a case such as this, sizing the energy storage at 125 or 150 percent of 2013 maximum output would maximize utilization of existing CRIS MW.

To examine which units may be candidates for hybridization or replacement with clean resources, solar is added to each of the storage sizing combinations above. The proposed NO_x regulations allow for generation from clean resources sited within a half mile radius of each SCCT to contribute to the total MWh included in the lb/MWh emissions rate calculation. Solar potential in the allowable area is estimated for each plant using Google Project Sunroof estimations of available rooftop.[33] For the downstate peakers it is assumed that there is limited land availability for solar siting and therefore only rooftop potential was considered, although ground mount is likely a viable option in many cases for Long Island plants. Twenty percent of the full technical solar potential was assumed to be developable. A flat solar potential of 10 MW is assumed available for peakers in Zones G and A. No development or ownership model was assumed in this study as individual facility owners must consider the specific options for compliance.

Hourly solar profiles at each generator location for 2013 are taken from the NREL SAM model[34]. The hourly profiles are for fixed roof mount solar PV with an inverter loading ratio of 1.3. Solar profiles are normalized on a per MW basis, and then scaled to the solar potential assumed at each site. Any solar production coincident with historical peaker operation is assumed to displace that generation. Any remaining generation from the peaker would then be displaced by the storage. Due to the limited solar potential surrounding the peaker plants, replacement or hybridization without storage is not considered feasible and was not explicitly modeled.

[32] Each unit's 2013 peak output was compared against its maximum load from 2009-2018 and the 2013 peak was found to be representative for most of the fleet. A small number of units (<10) have peaks greater than 5 MW higher in years other than 2013.
[33] See Google Project Sunroof. Available at: https://www.google.com/get/sunroof. Total technical rooftop potential in each county is used to estimate the potential surrounding each plant and scaled to represent a footprint of one-half mile radius. The solar potential in any overlapping area around neighboring facilities is divided equally between the facilities.
[34] See the National Renewable Energy Laboratory System Advisor Model. Available at: https://sam.nrel.gov/.

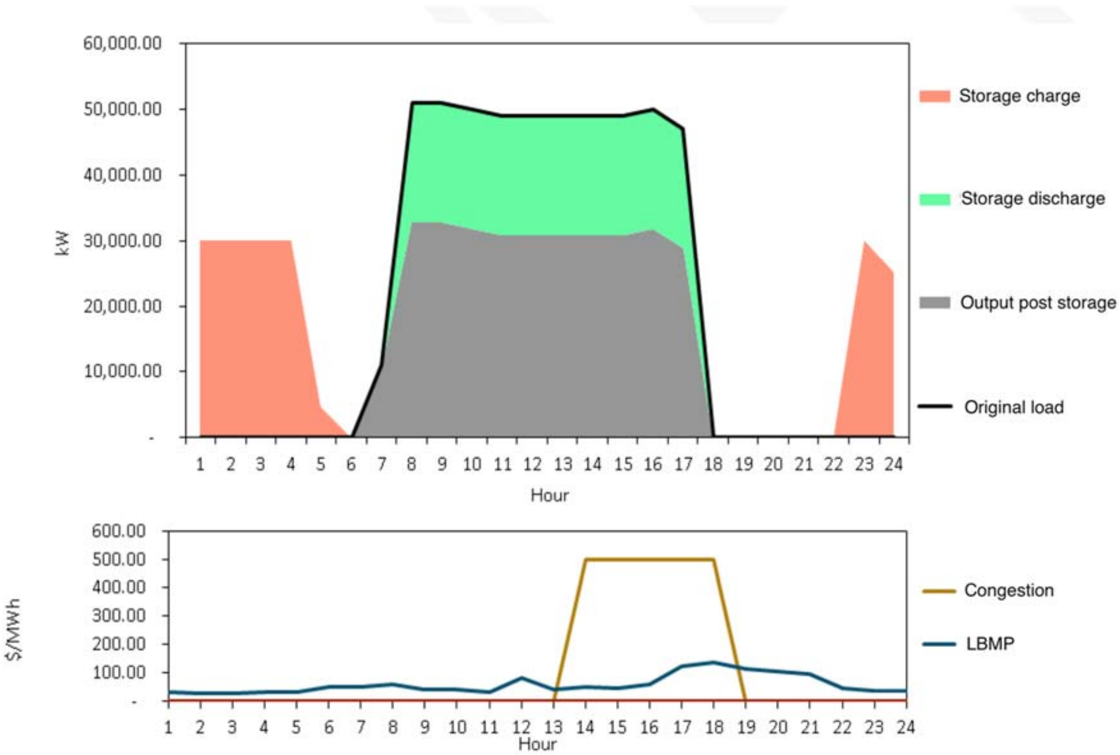
The hourly storage dispatch under each scenario is compared to the historical peaker-only operations to determine if storage can fully displace the unit output. Any units that are found to have no output after storage has been dispatched are considered potential candidates for replacement. This is repeated for each storage size and duration combination.

The hourly storage dispatch under each scenario is also used to determine the potential candidates for hybridization to meet the proposed NO_x regulations. Both the initial and more stringent NO_x limitations are examined. Any units that are found to have no days of NOx exceedance of the 3 lb/MWh limit after storage has been dispatched are considered potential candidates for hybridization to meet the proposed 2023 NOx limitations. Any units that are found to have no days of NOx exceedance of the 1.5 lb/MWh or 2.0 lb/MWh limit after storage has been dispatched are considered potential candidates for hybridization to meet the proposed 2025 NO_x limitations.[35]

An example dispatch chart from the storage optimization tool is shown below for a day in which the unit operated, and the storage is dispatched to displace that generation. The figure below shows an instance where the peaker is not a candidate for replacement because there is still some unit generation that could not be displaced with storage. Further assessments are then done to determine the total average lb/MWh NO_x rate of the combined output to determine if the peaker could potentially be a hybridization candidate.

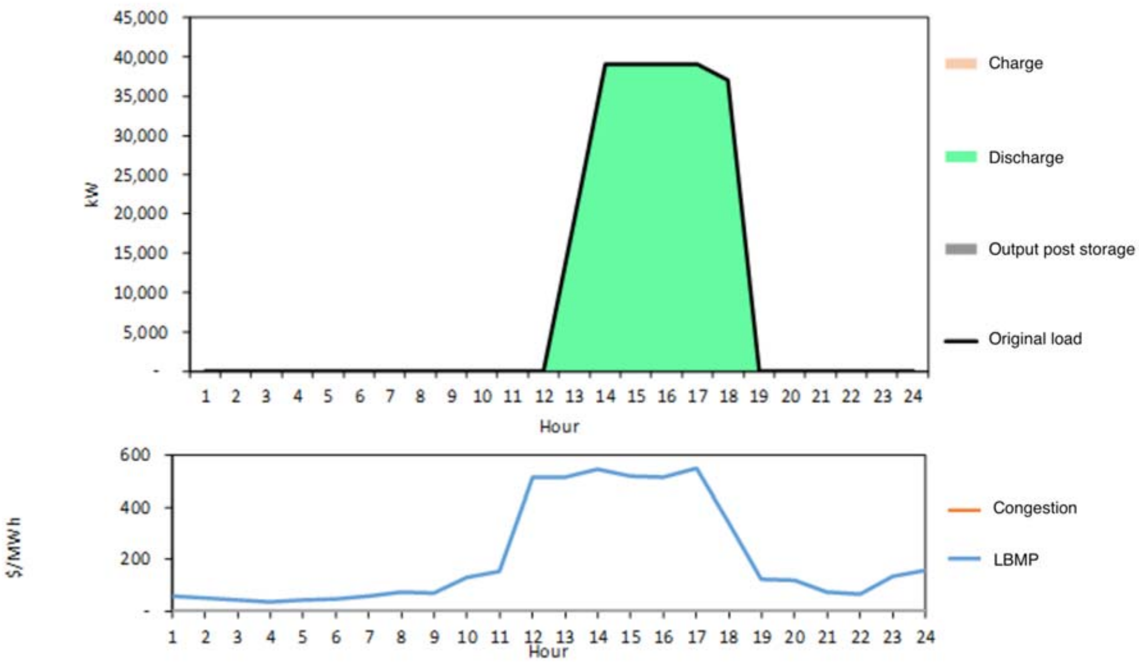
[35] Proposed Part 227-3 Express Terms.

Figure 4: Illustrative Dispatch Chart Showing Storage Partially Displacing Peaker Output



The following is a dispatch chart for a unit that would be considered a good potential candidate for replacement. Under these storage sizing assumptions, the unit's generation output could be completely replaced.

Figure 5: Illustrative Dispatch Chart Showing Storage Fully Displacing Peaker Output



3.3 Reliability Screens

In its assessment of DEC's proposed NO_x rule, the NYISO found that if all affected generators, estimated at approximately 3,300 MW in the NYISO study, were shut down without additional replacement resources or system reinforcements there would be supply deficiencies in New York and Long Island beginning in 2023, reaching a combined system deficiency of at least 700 MW in 2025. The NYISO also found that local deficiencies in the Con Edison and LIPA territories would reach 660 MW and 620 MW respectively by 2028. The duration of these supply deficiencies is an important consideration and the NYISO notes that reliability solutions would need to address the peak megawatt deficiency as well as the total megawatt-hour deficiency over the specified period.

The candidates identified in this report represent the peaking units that show potential for storage replacement or hybridization from an operational perspective. The analysis does not speak to reliability solutions for units that may be retired due to policy or economic drivers where energy storage is not found to be a suitable alternative replacement resource. As discussed in Section 2.2, no power flow modeling was performed for this analysis.

Based on existing studies a total of 2,058 MW nameplate and 1,645 MW summer capability within Con Edison's service territory are affected by the regulations. The transmission security and operational impacts highlighted in Con Edison's impact assessment include a design deficiency of 220 MW in the Astoria East/Corona 138 kW transmission load area (TLA) and a 20

MW of distribution deficiency in the East 75th Street Area Station beginning in 2023. In 2025, with added retirements there is an additional deficiency of 420 MW in the Greenwood/Fox Hills TLA.

For LIPA, peaker retirements with no replacement resources were shown to result in a 620 MW deficiency in 2025, with the majority of the deficiency driven by forecasted load growth in East End pocket and assumed generator retirements. LIPA notes that absent alternative solutions including local transmission plan system upgrades, deactivation of the peaking units would significantly impact the flexibility to accommodate system maintenance or outages.

4 Results

The results of the unit by unit replacement and hybridization analysis are presented below for the range of storage power and energy capacities tested and include the impact of adding solar to the modeled storage systems. Overall, 12 units representing 275 MW of nameplate capacity are potential candidates for replacement with 6-hour storage; adding solar causes an additional unit (25 MW) to become a candidate. When considering storage's ability to hybridize peaking units and bring them into compliance with the proposed 2025 NO_x limit, the study found that 864 MW of peaking units may be brought into compliance by adding 4-hour storage.[36] This is comparable to the MW value of resource adequacy need noted in the NYISO CRP peaker scenario. Adding solar to the sites in this scenario allows over 1,500 MW to potentially be brought into compliance and would satisfy much of the deficiency reported by the utilities, depending on the findings of additional electric system reliability analysis.

Table 5: Total nameplate capacity of peaking units that can potentially be replaced with storage to meet the 2025 NO_x limits at 100 percent sizing

Energy Storage Unit Hours of Operation				
	NYISO Zone	**4**	**6**	**8**
Standalone Energy Storage	Zone K	16	122	227
	Zone J	20	107	236
	Rest of State	47	47	47
	Total	**83**	**275**	**509**
Energy Storage Paired with Solar	Zone K	32	122	227
	Zone J	73	132	288
	Rest of State	47	47	47
	Total	**152**	**300**	**562**

[36] Units are modeled with access to the total solar potential assumed for each site, which may overestimate the total combined number of candidates under the solar scenarios.

Table 6: Total nameplate capacity of peaking units that can potentially be hybridized with storage to meet the 2025 NO_x limits at 100 percent sizing

		Energy Storage Unit Hours of Operation		
	NYISO Zone	**4**	**6**	**8**
Standalone Energy Storage	Zone K	743	883	883
	Zone J	74	195	477
	Rest of State	47	47	47
	Total	**864**	**1,125**	**1,407**
Energy Storage Paired with Solar	Zone K	876	1,015	1,129
	Zone J	627	742	1,135
	Rest of State	47	47	88
	Total	**1,550**	**1,804**	**2,352**

4.1 Replacement Potential

The tables below show the total number of units and MW that are fully replaceable by storage, or storage paired with solar, under different durations based on 2013 operational data. The results shown are for energy storage sized at 150 percent of the peak 2013 output, and are comparable to sizing storage to winter CRIS.

Table 7: Replacement candidates under various storage sizing assumptions, $100 congestion threshold

Capacity (% of maximum output)	Duration (Hours)	Number of units that are candidates for replacement	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity analyzed	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
100	**4**	3	83	2%	4	332	6,108	3	2
	6	12	275	6%	6	3,676	45,547	5	5
	8	18	509	11%	7	18,154	156,086	9	9
125	**4**	9	224	5%	5	2,244	28,385	5	4
	6	17	467	10%	7	14,306	129,386	8	8
	8	46	1,607	36%	10	158,582	1,394,843	20	20
150	**4**	12	275	6%	6	3,676	45,547	5	5
	6	29	822	18%	8	49,042	366,121	13	13
	8	65	2,369	53%	11	350,781	2,008,815	22	23

Table 8: Replacement candidates under various storage sizing assumptions paired with solar, $100 congestion threshold

Capacity (% of maximum output)	Duration (Hours)	Number of units that are candidates for replacement	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity analyzed	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
100	**4**	7	152	3%	5	1,016	15,495	3	3
	6	13	300	7%	6	4,630	49,034	6	6
	8	21	562	13%	7	19,611	164,497	10	9
125	**4**	11	256	6%	5	2,789	33,460	5	5
	6	19	502	11%	7	15,013	134,778	8	8
	8	52	1,764	39%	10	196,424	1,659,622	23	24
150	**4**	13	300	7%	6	4,630	49,034	6	6
	6	35	1,033	23%	9	79,442	556,192	15	16
	8	69	2,453	55%	12	385,326	2,262,488	24	25

4.2 Hybridization Potential

Although the proposed DEC NO_x rule is measured on a facility-level average across all units, hybridization potential is presented in terms of individual units that meet the proposed daily average NO_x emissions limits for 2025 with the addition of storage or storage and solar.[37] The analysis is performed on a unit by unit basis to inform which units are better suited for hybridization. A combination of different compliance options may be implemented across individual units at each facility and prescribing a specific plant-wide strategy is beyond the scope of this analysis.

[37] Results for hybridization candidates under the 2023 limit of 3 lb/MWh are shown in Appendix E: Additional Results

Table 9: Hybridization candidates to meet 2025 limit under various storage sizing assumptions, $100 congestion threshold

Capacity (% of maximum output)	Hours	Number of units	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity analyzed	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
25	**4**	9	461	10%	318	64,621	9,596	2	2
	6	9	461	10%	318	89,383	12,677	2	2
	8	9	461	10%	318	108,642	14,887	2	2
50	**4**	9	461	10%	318	127,889	18,657	2	2
	6	10	522	12%	288	199,130	28,254	2	2
	8	11	601	13%	263	250,891	53,863	2	5
75	**4**	10	522	12%	288	214,346	31,408	2	2
	6	17	785	18%	173	309,999	99,718	5	6
	8	23	968	22%	131	383,488	183,052	6	8
100	**4**	20	864	19%	147	292,118	98,386	3	5
	6	30	1,124	25%	101	407,390	205,245	5	7
	8	40	1,407	31%	78	510,472	387,163	8	9

Table 10: Hybridization candidates to meet 2025 limit under various storage sizing assumptions paired with solar, $100 congestion threshold

Capacity (% of peak output)	Hours	Number of units	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
25	4	21	1,064	24%	169	164,347	27,853	3	4
	6	21	1,064	24%	169	212,643	35,025	3	4
	8	21	1,064	24%	169	249,164	40,314	3	4
50	4	21	1,064	24%	169	301,598	50,038	3	4
	6	23	1,140	25%	155	419,834	70,327	4	4
	8	26	1,270	28%	139	507,729	107,874	4	6
75	4	27	1,214	27%	133	461,670	83,114	4	4
	6	36	1,518	34%	102	627,681	173,428	4	6
	8	43	1,737	39%	87	753,849	284,525	6	7
100	4	36	1,549	35%	102	603,798	165,884	4	6
	6	45	1,803	40%	83	803,142	306,741	6	7
	8	60	2,352	53%	65	1,004,687	825,796	10	11

5 Discussion

The results presented in Section 4 highlight that under peak load year conditions, many units in the peaker fleet had operating characteristics that made them potential candidates for replacement with 4-8 hour energy storage systems. These results are in line with the earlier analysis presented in the Energy Storage Roadmap, which can be found in Resource adequacy is a critical concern especially in systems such as New York City and Long Island that have high reliability value and that are already constrained by existing transmission and generation limitations.

As systems transition from primarily thermal resources to ones with more renewables, storage and demand response (DR) resources, determining resource adequacy and reliability needs becomes more complex. This means existing rules of thumb, methodologies and models need to be updated or replaced with ones that are more suited to determining the reliability needs of the future system. For more decarbonized systems, reliability hinges on renewable availability, which is weather dependent, while storage and demand response availability depends on multiple factors.

For renewables, storage, and demand-side resources, there are both saturation and interactive effects that must be accounted for which makes a generic rule of thumb difficult to apply to a particular resource without knowing the installed quantity of that resource or other resources on the system. In order to ensure that a system has adequate resources, a model that is capable of calculating the capacity value and reliability contribution of these resources that can account for both the diminishing saturation effects of resources as well as the interactive effects between different resources should be used.

Analytical tools used for reliability planning capture thermal resource and transmission forced outages and these tools are being expanded to include more time-sequential approaches that better account for variability of renewables and correlations to load as well as better tracking of hydro and storage state-of-charge. These time-sequential approaches to reliability can better capture the energy-limited aspect of storage and demand response resources in the following manner:

- State-of-charge (storage) and number of calls (DR) can be tracked, limiting the availability of shorter-duration storage and limited-call DR resources
- Storage/DR dispatch would only discharge for reliability when all other resources are not sufficient; storage would charge at the first available opportunity
- Storage/DR capacity and reliability value should be quantified endogenously, recalculating dispatch and charging schedules according to system needs and availability. This means system conditions can affect capacity and reliability value, e.g. more renewables tend to increase capacity value of storage due to synergistic effects of peakier reliability needs that are more well suited to being met with storage

Separate from the approach described above, the NYISO conducts long-term planning analysis through its Reliability Planning Process as part of its Comprehensive System Planning Process (CSPP). Con Edison/ LIPA also have contingency planning methods to ensure reliability criteria are maintained. These studies include the NYISO's Reliability Needs Assessments, Comprehensive Reliability Plans, Generator Deactivation Assessments, and Interconnection processes. As the mix of resources interconnected to the electric grid changes, it will be important to evaluate prevailing reliability assessment methodologies to ensure the contribution of energy storage and renewables to grid reliability is properly considered.

Storage hybridization also appears to be a viable compliance option for meeting the proposed DEC NOx limits for many units. This option may also contribute to addressing reliability needs while limiting local emissions to regulated levels. Being able to site solar resources near the units could also allow more units to be fully replaced and/or hybridized. This option will likely be very site specific and the best locations for solar resources may not align with the units that are potential replacement and/or hybridization candidates.

Overall, the level of congestion was found to have limited impact on the replacement and hybridization candidates identified. At larger storage sizes and greater durations however, the results become more sensitive to congestion constraints. The results indicate that at smaller sizes the total energy capacity of the storage is the binding constraint in terms of the amount of a unit's generation that can be replaced or displaced, while at larger sizes the limitations on charging times become more binding.

The results for the replacement potential do not appear to violate the overall reliability assessments already performed by Con Edison and LIPA in terms of total MWs, but there could be other reliability issues that a more detailed study would be required to address. Further studies should explore which units are critical to a specific load pocket or for contingency reserves, as well as how the system reliability needs will change in the future given current state policy goals. While this study is not a replacement for a detailed reliability needs assessment or an analysis on the potential power flow charging constraints of different storage configurations, this study identified a number of potentially suitable candidates for replacement and/or hybridization. There also appears to be sufficient uncongested hours in most peaker locations, indicating a system that is likely able to charge the storage and enable displacement of a unit's generation.

While there are achievable cost savings from avoided fuel and operating expenses, a detailed benefit-cost analysis over the lifecycle of each facility would need to be performed to understand the overall economics of each facility and unit including the additional benefits and revenues available to energy storage as well as any other associated costs. Different compliance options or combinations of compliance strategies may be deployed for individual units to meet the plant-wide NO_x limits. The costs and benefits of different compliance strategies will vary.

Hybridization is only one of the compliance options and this analysis is not meant to be prescriptive or imply that all hybridization candidates will or should pursue hybridization as a compliance option, but the analysis does provide an indication of the total potential of that particular compliance option.

6 Conclusions and Recommendations for Further Study

As discussed in Section 2.2, while there are a number of caveats and limitations to this analysis there are several important conclusions:

- At least 275 MW of units, or around 6 percent of the total fleet, are candidates for replacement with 6-hour storage sized to the peak 2013 output of each unit using the analytical methodology in this study including applying proxies for charging constraints. This number increases to over 500 MW for 8-hour duration.
- If energy storage capacity is oversized (i.e. power capacity of greater than 100 percent of peak 2013 output) additional units become candidates. For example, sizing storage to 125 percent of peak output at a 4-hour duration results in 224 MW of replacement candidates, more than the 2.5 times the replacement capacity found at 100 percent sizing and 4-hour duration. The effects are even more dramatic for the 6- and 8-hour duration results with replacement capacity increasing to 467 MW and 1,607 MW, respectively.
    - In many cases "oversizing" based on peak output still leads to storage sized below the nameplate and winter CRIS of the units.
    - The decision to oversize will be a tradeoff between the relative costs of storage capacity, duration, interconnection and siting as well as any potential constraints on charging capacity.
- Energy storage or a combination of energy storage and solar can contribute towards meeting NO_x limits for a large number of units; however, the minimum size storage required to meet the NO_x requirements can vary between units of the same facility. A facility-wide strategy to meet the NO_x limits should therefore consider a combination of different compliance options across units. Facility-wide compliance strategies are not examined or prescribed in this report.
- A more detailed analysis will be needed to understand the reliability impacts of specific unit replacements, especially as loads and resources change with greater electrification of transport and buildings and higher penetrations of renewables.
- A more detailed analysis would be needed to estimate the true solar potential around each candidate site, but these results indicate that adding solar to energy storage could be one viable way to contribute to NO_x compliance for units.
- A more detailed and thorough benefit-cost analysis would need to be performed to understand the true economic viability of the replacement and/or hybridization options presented in this analysis.
- Overall, the findings suggest that there is an opportunity to consider replacing or hybridizing a substantial portion of the peaking units subject to DEC's proposed NO_x rule with a fleet of storage resources paired with solar. Such an outcome would potentially deliver significant environmental benefits, advance the state's carbon reduction and clean energy goals, as well as benefit historically disadvantaged populations and communities such as environmental justice areas in line with the goals of the Climate Leadership and Community Protection Act.

Appendix A: List of Units Examined in this Study

The following units are included in the analysis. Units that have been mothballed or retired since operating in 2013 have been excluded from the results of potential candidates for hybridization and/or replacement.

Table A1: Peaking Unit Data

Plant Name	ORISPL CODE	UNITID	Generator ID	PTID	Age	Nameplate Capacity (MW)	Summer Capacity (MW)	Winter Capacity (MW)	Average 2013 NOx rate (lb/MWh)
Arthur Kill Generating Station	2490	CT0001	GT1	23520	49	18	12	15	4.0
Gowanus Gas Turbines Generating	2494	CT01-1	GT11	24077	48	20	18.9	24.5	11.8
Gowanus Gas Turbines Generating	2494	CT01-2	GT12	24078	48	20	18.5	20.8	11.8
Gowanus Gas Turbines Generating	2494	CT01-3	GT13	24079	48	20	15.2	22	11.8
Gowanus Gas Turbines Generating	2494	CT01-4	GT14	24080	48	20	16	20.9	11.8
Gowanus Gas Turbines Generating	2494	CT01-5	GT15	24084	48	20	16	20.9	11.8
Gowanus Gas Turbines Generating	2494	CT01-6	GT16	24111	48	20	16.9	22.4	11.8
Gowanus Gas Turbines Generating	2494	CT01-7	GT17	24112	48	20	16.8	21.5	11.8
Gowanus Gas Turbines Generating	2494	CT01-8	GT18	24113	48	20	15.5	19.9	11.8
Gowanus Gas Turbines Generating	2494	CT02-1	GT21	24114	48	20	17	22	4.9
Gowanus Gas Turbines Generating	2494	CT02-2	GT22	24115	48	20	18.1	23.9	4.9
Gowanus Gas Turbines Generating	2494	CT02-3	GT23	24116	48	20	19.2	24.2	4.9
Gowanus Gas Turbines Generating	2494	CT02-4	GT24	24117	48	20	17.1	22.8	4.9
Gowanus Gas Turbines Generating	2494	CT02-5	GT25	24118	48	20	17.4	22.2	4.9
Gowanus Gas Turbines Generating	2494	CT02-6	GT26	24119	48	20	18.9	24.4	4.9
Gowanus Gas Turbines Generating	2494	CT02-7	GT27	24120	48	20	18.7	23.7	4.9
Gowanus Gas Turbines Generating	2494	CT02-8	GT28	24121	48	20	17	21.6	4.9
Gowanus Gas Turbines Generating	2494	CT03-1	GT31	24122	48	20	16.6	21.7	5.0
Gowanus Gas Turbines Generating	2494	CT03-2	GT32	24123	48	20	16.6	21.7	5.0
Gowanus Gas Turbines Generating	2494	CT03-3	GT33	24124	48	20	18.2	23.6	4.9
Gowanus Gas Turbines Generating	2494	CT03-4	GT34	24125	48	20	16.3	21	5.0
Gowanus Gas Turbines Generating	2494	CT03-5	GT35	24126	48	20	18.5	22.9	5.0
Gowanus Gas Turbines Generating	2494	CT03-6	GT36	24127	48	20	16.2	20	4.9
Gowanus Gas Turbines Generating	2494	CT03-7	GT37	24128	48	20	16.9	21.7	5.0
Gowanus Gas Turbines Generating	2494	CT03-8	GT38	24129	48	20	17.4	23.4	5.0

Gowanus Gas Turbines Generating	2494	CT04-1	GT41	24130	48	20	14.6	20.6	11.8
Gowanus Gas Turbines Generating	2494	CT04-2	GT42	24131	48	20	17.4	23	11.8
Gowanus Gas Turbines Generating	2494	CT04-3	GT43	24132	48	20	17.5	23.4	11.8
Gowanus Gas Turbines Generating	2494	CT04-4	GT44	24133	48	20	15.9	21.7	11.8
Gowanus Gas Turbines Generating	2494	CT04-5	GT45	24134	48	20	16.1	20.7	11.8
Gowanus Gas Turbines Generating	2494	CT04-6	GT46	24135	48	20	17.9	22.6	11.8
Gowanus Gas Turbines Generating	2494	CT04-7	GT47	24136	48	20	16.6	21.6	11.8
Gowanus Gas Turbines Generating	2494	CT04-8	GT48	24137	48	20	17.5	23.3	11.8
Hudson Avenue	2496	CT0003	GT3	23810	49	16.3	14.3	18.7	9.9
Hudson Avenue	2496	CT0004	4	23540	49	16.3	14.6	17.5	8.1
Hudson Avenue	2496	CT0005	GT5	23657	49	16.3	15.7	18.6	10.1
Narrows Gas Turbines Generating	2499	CT01-1	NT11	24228	47	22	18.7	24.7	6.3
Narrows Gas Turbines Generating	2499	CT01-2	NT12	24229	47	22	16.9	23.4	6.4
Narrows Gas Turbines Generating	2499	CT01-3	NT13	24230	47	22	18.4	24.3	6.3
Narrows Gas Turbines Generating	2499	CT01-4	NT14	24231	47	22	18.8	24.9	6.3
Narrows Gas Turbines Generating	2499	CT01-5	NT15	24232	47	22	18.7	24.4	6.3
Narrows Gas Turbines Generating	2499	CT01-6	NT16	24233	47	22	17.1	23.7	6.3
Narrows Gas Turbines Generating	2499	CT01-7	NT17	24234	47	22	17.4	23	6.3
Narrows Gas Turbines Generating	2499	CT01-8	NT18	24235	47	22	17.3	22.2	6.4
Narrows Gas Turbines Generating	2499	CT02-1	NT21	24236	47	22	18.5	23.8	6.4
Narrows Gas Turbines Generating	2499	CT02-2	NT22	24237	47	22	17.8	22.2	6.4
Narrows Gas Turbines Generating	2499	CT02-3	NT23	24238	47	22	17	22.4	6.4
Narrows Gas Turbines Generating	2499	CT02-4	NT24	24239	47	22	18.3	23.6	6.4
Narrows Gas Turbines Generating	2499	CT02-5	NT25	24240	47	22	18.2	23.7	6.4
Narrows Gas Turbines Generating	2499	CT02-6	NT26	24241	47	22	16.5	21.2	6.4
Narrows Gas Turbines Generating	2499	CT02-7	NT27	24242	47	22	19	23.9	6.4
Narrows Gas Turbines Generating	2499	CT02-8	NT28	24243	47	22	17.4	21.4	6.4
Ravenswood	2500	CT0001	GT1	23729	52	18.6	7.9	9.6	5.9
Ravenswood	2500	CT0010	GT10	24258	50	25	17.8	22.8	3.6
Ravenswood	2500	CT0011	GT11	24259	50	25	17.5	22.8	2.2

59th Street	2503	CT0001	GT1	24138	50	17.1	15.4	20.7	6.7
74th Street	2504	CT0001	GT1	24260	51	18.5	10.2	17.9	8.6
74th Street	2504	CT0002	GT2	24261	51	18.5	18.4	20.1	8.6
East Hampton	2512	UGT001	1	23717	49	21.3	18.9	23.6	9.8
Glenwood	2514	U00020	GT2	23688	47	55	49.6	62	8.6
Glenwood	2514	U00021	GT3	23689	47	55	55.1	66.5	8.4
Northport	2516	UGT001	GT1	23718	52	16	12.4	15.9	29.1
Port Jefferson	2517	UGT001	GT1	23713	53	16	12.4	15.9	32.3
Port Jefferson*	2517	UGT002	GT2	24210	17	53	43.3	48.1	0.3
Port Jefferson*	2517	UGT003	GT3	24211	17	53	39.7	46	0.3
West Babylon	2521	UGT001	4	23714	48	52.4	49.9	62.9	9.3
Hillburn	2628	1	GEN1	23639	47	46.5	33.1	43.8	5.5
Shoemaker	2632	1	SHOE	23640	47	41.9	33	40	5.7
Plant No 2 Freeport*	2679	5	CT5	23818	15	60.5	49	49	1.6
Wading River	7146	UGT007	1	23522	30	79.5	78.5	97.2	2.0
Wading River	7146	UGT008	2	23547	30	79.5	77.5	101.3	3.8
Wading River	7146	UGT009	3	23601	30	79.5	75.9	96.5	5.7
Wading River	7146	UGT013	GT1	23715	48	52.9	47.7	62.8	9.0
Wading River	7146	UGT014	GT2	23716	53	18.6	15.4	22.2	13.7
Glenwood Landing	7869	UGT011	GT1	23712	52	16	11.8	17.2	47.8
Glenwood Landing*	7869	UGT012	GT4	24219	17	53	40.6	46	0.2
Glenwood Landing*	7869	UGT013	GT5	24220	17	53	38.6	44.6	0.2
Vernon Boulevard*	7909	VB01	VG02	24162	18	47	39.9	39.9	0.1
Vernon Boulevard*	7909	VB02	VG03	24163	18	47	40	40	0.2
Joseph J Seymour Power Project*	7910	2301	1	24156	18	47	39.9	39.9	0.1
Joseph J Seymour Power Project*	7910	2302	2	24157	18	47	40	40	0.1
Brentwood*	7912	BW01	1	24164	18	47	47	47	0.2
Hell Gate*	7913	HG01	HG01	24158	18	47	39.9	39.9	0.1
Hell Gate*	7913	HG02	HG02	24159	18	47	40	40	0.1
Harlem River Yard*	7914	HR01	HR01	24160	18	47	39.9	39.9	0.2
Harlem River Yard*	7914	HR02	HR02	24161	18	47	40	40	0.3
North 1st*	7915	NO1	N01	24152	18	47	47	47	0.2
Holtsville	8007	U1	1	23690	45	56.7	51.9	65.2	14.1
Holtsville	8007	U10	10	23699	44	56.7	52.2	65.9	12.1
Holtsville	8007	U2	2	23691	45	56.7	48.4	59.9	14.2
Holtsville	8007	U3	3	23692	45	56.7	47.3	62	11.5
Holtsville	8007	U4	4	23693	45	56.7	50.5	59.3	10.4
Holtsville	8007	U5	5	23694	45	56.7	51.5	63.7	12.7
Holtsville	8007	U6	6	23695	44	56.7	51.5	63.9	13.1
Holtsville	8007	U7	7	23696	44	56.7	51.1	60.2	12.3

Holtsville	8007	U8	8	23697	44	56.7	54.3	65.9	12.0
Holtsville	8007	U9	9	23698	44	56.7	54.3	68.5	13.1
Pouch*	8053	PT01	N01	24155	18	47	47	47	0.1
Astoria Generating Station	8906	CT0001	1	23523	52	15	15.1	18.4	8.5
Bethpage Power Plant*	50292	GT4	GEN5	32358 6	17	60	47	49.6	0.1
Astoria Gas Turbines	55243	CT2-1	2-1	24094	49	41.9	37.3	43.9	6.4
Astoria Gas Turbines	55243	CT2-2	2-2	24095	49	41.9	35.1	43.1	6.5
Astoria Gas Turbines	55243	CT2-3	2-3	24096	49	41.9	35.9	42.8	6.4
Astoria Gas Turbines	55243	CT2-4	2-4	24097	49	41.9	34.8	41.1	6.5
Astoria Gas Turbines	55243	CT3-1	3-1	24098	49	41.9	33.7	43	6.6
Astoria Gas Turbines	55243	CT3-2	3-2	24099	49	41.9	34.7	43	6.5
Astoria Gas Turbines	55243	CT3-3	3-3	24100	49	41.9	32.2	42.8	6.5
Astoria Gas Turbines	55243	CT3-4	3-4	24101	49	41.9	34.6	42.9	6.6
Astoria Gas Turbines	55243	CT4-1	4-1	24102	49	41.9	32.9	43.6	6.3
Astoria Gas Turbines	55243	CT4-2	4-2	24103	49	41.9	32.1	43.5	6.5
Astoria Gas Turbines	55243	CT4-3	4-3	24104	49	41.9	33	43.2	6.7
Astoria Gas Turbines	55243	CT4-4	4-4	24105	49	41.9	34	43.1	6.5
Edgewood Energy LLC*	55786	CT01	CT01	24216	17	50	42.5	47	0.5
Edgewood Energy LLC*	55786	CT02	CT02	24217	17	50	42.5	47	0.3
Shoreham Energy LLC*	55787	CT01	CT01	24213	17	50	42.5	47	3.7
Shoreham Energy LLC*	55787	CT02	CT02	24214	17	50	42.5	47	3.5
Hawkeye Energy Greenport LLC*	55969	U-01	U-01	23814	16	54	52.5	56.8	0.4
Equus Freeport Power*	56032	1	1	23764	15	60	47.9	49.2	0.4
E F Barrett	2511	U00004	4	23707	49	18	18	18	6.0
E F Barrett	2511	U00005	5	23708	49	16	16	16	5.8
E F Barrett	2511	U00006	6	23709	49	18	18	18	5.8
E F Barrett	2511	U00007		23710	49	18	18	18	5.9
E F Barrett	2511	U00008	8	23711	49	18	18	18	5.7
E F Barrett	2511	U00009	9	23700	49	18	18	18	5.8
E F Barrett	2511	U00010	10	23701	49	18	18	18	0.0
E F Barrett	2511	U00011	11	23702	49	19	19	19	5.8
E F Barrett	2511	U00012	12	23703	49	23	23	23	7.4
E F Barrett	2511	U00013			49	23	23	23	7.4
E F Barrett	2511	U00014			49	22	22	22	7.4
E F Barrett	2511	U00015			49	22	22	22	7.4
E F Barrett	2511	U00016			49	23	23	23	7.4
E F Barrett	2511	U00017			49	23	23	23	7.4
E F Barrett	2511	U00018			49	22	22	22	7.4
E F Barrett	2511	U00019			49	22	22	22	7.4

S A Carlson*	2682	20	7	32375 1	18	47.3	42	47	1.3
Stony Brook Cogen Plant*	54149	1	GEN1	24151	24	47	44.5	47.1	0.9

** Units may be able to comply with future NOx limits due to existing emissions controls*

Below is a list of mothballed or otherwise out-of-service units that were in service in 2013, but not included in this analysis:

Table A2: Mothballed or otherwise out-of-service units not analyzed

Plant Name	ORISPL Code	Unit ID	Generator ID	PTID	Age	Nameplate Capacity (MW)
Astoria Gas Turbines	55243	CT0005	5	24106	49	16.3
Astoria Gas Turbines	55243	CT0007	7	24107	49	16.3
Astoria Gas Turbines	55243	CT0008	8	24108	49	16.3
Astoria Gas Turbines	55243	CT0010	10	24110	48	23.8
Astoria Gas Turbines	55243	CT0011	11	24225	48	23.8
Astoria Gas Turbines	55243	CT0012	12	24226	48	23.8
Astoria Gas Turbines	55243	CT0013	13	24227	48	23.8
Ravenswood	2500	CT02-1	GT21	24244	50	42.9
Ravenswood	2500	CT02-2	GT22	24245	50	42.9
Ravenswood	2500	CT02-3	GT23	24246	50	42.9
Ravenswood	2500	CT02-4	GT24	24247	50	42.9
Ravenswood	2500	CT03-1	GT31	24248	50	42.9
Ravenswood	2500	CT03-2	GT32	24249	50	42.9
Ravenswood	2500	CT03-3	GT33	24250	50	42.9
Ravenswood	2500	CT03-4	GT34	24251	50	42.9
Ravenswood	2500	CT0004	GT4	24252	50	21.1
Ravenswood	2500	CT0006	GT6	24253	50	22
Ravenswood	2500	CT0005	GT5	24254	50	21.1
Ravenswood	2500	CT0007	GT7	24255	50	22
Ravenswood	2500	CT0009	GT9	24257	50	25

Appendix B: Unit Specific Results

Table B1: Peaking unit replacement and hybridization results

Plant Name	ORISPL Code	Unit ID	NYISO PTID	Zone	2013 Peak Load (MW)	Nameplate Capacity (MW)	Ozone season only?	Solar (MW, if applicable)	Smallest storage for full replacement	Smallest storage for hybridization to meet 2025 limit	Smallest storage for hybridization to meet 2023 limit
Arthur Kill Generating Station	**2490**	**CT0001**	**23520**	**J**	**15**	**18**	**Yes**	**2.7**	8 hours, 100% of peak load	4 hours, 125% of peak load	6 hours, 25% of peak load
								-	6 hours, 150% of peak load	4 hours, 150% of peak load	4 hours, 75% of peak load
Gowanus Gas Turbines Generating	**2494**	**CT01-1**	**24077**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	8 hours, 150% of peak load
								-	None	None	None
		CT01-2	**24078**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	8 hours, 150% of peak load
								-	None	None	None
		CT01-3	**24079**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	8 hours, 150% of peak load
								-	None	None	None
		CT01-4	**24080**	**J**	**16**	**20**	**Yes**	**4.2**	None	8 hours, 150% of peak load	8 hours, 125% of peak load
								-	None	None	8 hours, 150% of peak load
		CT01-5	**24084**	**J**	**16**	**20**	**Yes**	**4.2**	6 hours, 125% of peak load	4 hours, 150% of peak load	6 hours, 75% of peak load
								-	6 hours, 125% of peak load	4 hours, 150% of peak load	4 hours, 125% of peak load
		CT01-6	**24111**	**J**	**16**	**20**	**Yes**	**4.2**	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
								-	None	8 hours, 150% of peak load	8 hours, 125% of peak load
		CT01-7	**24112**	**J**	**16**	**20**	**Yes**	**4.2**	None	8 hours, 150% of peak load	8 hours, 125% of peak load
								-	None	8 hours, 150% of peak load	8 hours, 150% of peak load
		CT01-8	**24113**	**J**	**16**	**20**	**Yes**	**4.2**	None	8 hours, 150% of peak load	8 hours, 125% of peak load
								-	None	None	8 hours, 150% of peak load
		CT02-1	**24114**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 150% of peak load
								-	None	None	None
		CT02-2	**24115**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 150% of peak load
								-	None	None	None
		CT02-3	**24116**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT02-4	**24117**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT02-5	**24118**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT02-6	**24119**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT02-7	**24120**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT02-8	**24121**	**J**	**16**	**20**	**Yes**	**4.2**	None	None	6 hours, 125% of peak load
								-	None	None	6 hours, 150% of peak load
		CT03-1	**24122**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None

		CT03-2	**24123**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT03-3	**24124**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT03-4	**24125**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT03-5	**24126**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT03-6	**24127**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT03-7	**24128**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	4 hours, 150% of peak load
								-	None	None	6 hours, 125% of peak load
		CT03-8	**24129**	**J**	**15**	**20**	**Yes**	**4.2**	None	None	None
								-	None	None	None
		CT04-1	**24130**	**J**	**15**	**20**	**Yes**	**4.2**	8 hours, 150% of peak load	6 hours, 150% of peak load	8 hours, 100% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
		CT04-2	**24131**	**J**	**15**	**20**	**Yes**	**4.2**	8 hours, 150% of peak load	6 hours, 150% of peak load	8 hours, 100% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
		CT04-3	**24132**	**J**	**15**	**20**	**Yes**	**4.2**	6 hours, 150% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
		CT04-4	**24133**	**J**	**15**	**20**	**Yes**	**4.2**	6 hours, 150% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
		CT04-5	**24134**	**J**	**15**	**20**	**Yes**	**4.2**	6 hours, 150% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
		CT04-6	**24135**	**J**	**15**	**20**	**Yes**	**4.2**	4 hours, 100% of peak load	4 hours, 75% of peak load	4 hours, 75% of peak load
								-	4 hours, 100% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
		CT04-7	**24136**	**J**	**15**	**20**	**Yes**	**4.2**	8 hours, 125% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		CT04-8	**24137**	**J**	**15**	**20**	**Yes**	**4.2**	6 hours, 150% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
Hudson Avenue	**2496**	**CT0003**	**23810**	**J**	**14**	**16.3**	**Yes**	**6.3**	4 hours, 100% of peak load	4 hours, 75% of peak load	4 hours, 50% of peak load
								-	4 hours, 150% of peak load	4 hours, 125% of peak load	4 hours, 100% of peak load
		CT0004	**23540**	**J**	**14**	**16.3**	**Yes**	**6.3**	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
								-	4 hours, 150% of peak load	4 hours, 125% of peak load	4 hours, 100% of peak load
		CT0005	**23657**	**J**	**14**	**16.3**	**Yes**	**6.3**	6 hours, 125% of peak load	4 hours, 150% of peak load	6 hours, 75% of peak load
								-	6 hours, 150% of peak load	6 hours, 125% of peak load	6 hours, 125% of peak load
Narrows Gas Turbines Generating	**2499**	**CT01-1**	**24228**	**J**	**17**	**22**	**Yes**	**6.3**	None	None	None
								-	None	None	None
		CT01-2	**24229**	**J**	**17**	**22**	**Yes**	**6.3**	None	None	None
								-	None	None	None
		CT01-3	**24230**	**J**	**17**	**22**	**Yes**	**6.3**	None	None	None

								-	None	None	None
		CT01-4	24231	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT01-5	24232	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT01-6	24233	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT01-7	24234	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT01-8	24235	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-1	24236	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-2	24237	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-3	24238	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-4	24239	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-5	24240	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-6	24241	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-7	24242	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
		CT02-8	24243	J	17	22	Yes	6.3	None	None	None
								-	None	None	None
Ravenswood	**2500**	**CT0001**	**23729**	**J**	**9**	**18.6**	**Yes**	**4**	6 hours, 125% of peak load	4 hours, 150% of peak load	4 hours, 100% of peak load
								-	8 hours, 125% of peak load	8 hours, 100% of peak load	4 hours, 150% of peak load
		CT0010	**24258**	**J**	**20**	**25**	**Yes**	**4**	4 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 25% of peak load
								-	6 hours, 125% of peak load	6 hours, 75% of peak load	6 hours, 25% of peak load
		CT0011	**24259**	**J**	**20**	**25**	**Yes**	**4**	6 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 100% of peak load
								-	8 hours, 150% of peak load	4 hours, 125% of peak load	4 hours, 125% of peak load
59th Street	**2503**	**CT0001**	**24138**	**J**	**14**	**17.1**	**Yes**	**4.4**	4 hours, 125% of peak load	4 hours, 75% of peak load	4 hours, 50% of peak load
								-	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
74th Street	**2504**	**CT0001**	**24260**	**J**	**14**	**18.5**	**Yes**	**4.4**	4 hours, 100% of peak load	4 hours, 75% of peak load	4 hours, 75% of peak load
								-	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
		CT0002	**24261**	**J**	**14**	**18.5**	**Yes**	**4.4**	4 hours, 100% of peak load	4 hours, 75% of peak load	4 hours, 75% of peak load
								-	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
E F Barrett	**2511**	**U00004**	**23707**	**K**	**18**	**18**	**No**	**2.3**	8 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 125% of peak load
								-	None	8 hours, 150% of peak load	4 hours, 150% of peak load

		U00005	**23708**	**K**	**16**	**16**	**No**	**2.3**	None	None	None
								-	None	None	None
		U00006	**23709**	**K**	**18**	**18**	**No**	**2.3**	8 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	4 hours, 150% of peak load
		U00007	**23710**	**K**	**18**	**18**	**No**	**2.3**	None	8 hours, 150% of peak load	4 hours, 125% of peak load
								-	None	None	4 hours, 150% of peak load
		U00008	**23711**	**K**	**18**	**18**	**No**	**2.3**	None	None	None
								-	None	None	None
		U00009	**23700**	**K**	**18**	**18**	**No**	**2.3**	6 hours, 150% of peak load	4 hours, 150% of peak load	4 hours, 100% of peak load
								-	6 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 100% of peak load
		U00010	**23701**	**K**	**0**	**18**	**No**	**2.3**	None	None	None
								-	None	None	None
		U00011	**23702**	**K**	**19**	**19**	**No**	**2.3**	8 hours, 150% of peak load	8 hours, 150% of peak load	4 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	4 hours, 150% of peak load
		U00012	**23703**	**K**	**23**	**23**	**No**	**2.3**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 125% of peak load
		U00013	**0**	**K**	**23**	**23**	**No**	**2.3**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 125% of peak load
		U00014	**0**	**K**	**22**	**22**	**No**	**2.3**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 125% of peak load
		U00015	**0**	**K**	**22**	**22**	**No**	**2.3**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	6 hours, 125% of peak load
		U00016	**0**	**K**	**23**	**23**	**No**	**2.3**	8 hours, 150% of peak load	8 hours, 150% of peak load	6 hours, 125% of peak load
								-	None	8 hours, 150% of peak load	6 hours, 125% of peak load
		U00017	**0**	**K**	**23**	**23**	**No**	**2.3**	8 hours, 150% of peak load	8 hours, 150% of peak load	6 hours, 125% of peak load
								-	None	8 hours, 150% of peak load	6 hours, 125% of peak load
		U00018	**0**	**K**	**22**	**22**	**No**	**2.3**	None	8 hours, 150% of peak load	6 hours, 150% of peak load
								-	None	None	6 hours, 150% of peak load
		U00019	**0**	**K**	**22**	**22**	**No**	**2.3**	None	8 hours, 150% of peak load	6 hours, 150% of peak load
								-	None	None	6 hours, 150% of peak load
East Hampton	**2512**	**UGT001**	**23717**	**K**	**19**	**21.3**	**No**	**1.1**	None	None	None
								-	None	None	None
Glenwood	**2514**	**U00020**	**23688**	**K**	**59**	**55**	**No**	**1.2**	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
								-	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
		U00021	**23689**	**K**	**60**	**55**	**No**	**1.2**	6 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
								-	6 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 75% of peak load
Northport	**2516**	**UGT001**	**23718**	**K**	**15**	**16**	**No**	**1.1**	4 hours, 100% of peak load	6 hours, 75% of peak load	6 hours, 75% of peak load
								-	4 hours, 100% of peak load	6 hours, 75% of peak load	6 hours, 75% of peak load
Port Jefferson	**2517**	**UGT001**	**23713**	**K**	**16**	**16**	**No**	**1.1**	4 hours, 100% of peak load	6 hours, 75% of peak load	6 hours, 75% of peak load
								-	4 hours, 125% of peak load	4 hours, 100% of peak load	4 hours, 100% of peak load
			24210	**K**	**48**	**53**	**No**	**1.1**	None	4 hours, 25% of peak load	4 hours, 25% of peak load

		UGT002						-	None	None	None
		UGT003	**24211**	**K**	**47**	**53**	**No**	**1.1**	None	None	None
								-	None	None	None
West Babylon	**2521**	**UGT001**	**23714**	**K**	**59**	**52.4**	**No**	**1.1**	6 hours, 125% of peak load	4 hours, 150% of peak load	4 hours, 150% of peak load
								-	6 hours, 125% of peak load	4 hours, 150% of peak load	4 hours, 150% of peak load
Hillburn	**2628**	**001**	**23639**	**G**	**40**	**46.5**	**No**	**10**	4 hours, 100% of peak load	4 hours, 100% of peak load	4 hours, 100% of peak load
								-	4 hours, 100% of peak load	4 hours, 100% of peak load	4 hours, 100% of peak load
Shoemaker	**2632**	**1**	**23640**	**G**	**39**	**41.9**	**No**	**10**	8 hours, 125% of peak load	6 hours, 125% of peak load	4 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	8 hours, 150% of peak load
Plant No 2 Freeport	**2679**	**5**	**23818**	**K**	**50**	**60.5**	**No**	**1.2**	8 hours, 150% of peak load	4 hours, 75% of peak load	4 hours, 25% of peak load
								-	8 hours, 150% of peak load	4 hours, 75% of peak load	4 hours, 25% of peak load
S A Carlson	**2682**	**20**	**323751**	**A**	**45**	**47.3**	**No**	**10**	None	None	None
								-	None	None	None
Bethpage Power Plant	**50292**	**GT4**	**323586**	**K**	**83**	**60**	**No**	**2.3**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
Stony Brook Cogen Plant	**54149**	**1**	**24151**	**K**	**45**	**47**	**No**	**1.1**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
Astoria Gas Turbines	**55243**	**CT2-1**	**24094**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT2-2	**24095**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT2-3	**24096**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	8 hours, 100% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT2-4	**24097**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 125% of peak load	4 hours, 150% of peak load	4 hours, 100% of peak load
								-	6 hours, 125% of peak load	6 hours, 125% of peak load	6 hours, 75% of peak load
		CT3-1	**24098**	**J**	**40**	**41.9**	**No**	**3**	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT3-2	**24099**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	8 hours, 100% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT3-3	**24100**	**J**	**40**	**41.9**	**No**	**3**	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT3-4	**24101**	**J**	**40**	**41.9**	**No**	**3**	8 hours, 125% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
		CT4-1	**24102**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	8 hours, 100% of peak load	6 hours, 125% of peak load
								-	6 hours, 150% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		CT4-2	**24103**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	8 hours, 100% of peak load	4 hours, 150% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	4 hours, 150% of peak load
		CT4-3	**24104**	**J**	**40**	**41.9**	**No**	**3**	8 hours, 100% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	8 hours, 100% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
		CT4-4	**24105**	**J**	**40**	**41.9**	**No**	**3**	6 hours, 150% of peak load	6 hours, 125% of peak load	4 hours, 150% of peak load
								-	6 hours, 150% of peak load	8 hours, 100% of peak load	4 hours, 150% of peak load

Edgewood Energy LLC	**55786**	**CT01**	**24216**	**K**	**48**	**50**	**No**	**1.1**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
		CT02	**24217**	**K**	**49**	**50**	**No**	**1.1**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
Shoreham Energy LLC	**55787**	**CT01**	**24213**	**K**	**45**	**50**	**No**	**1.1**	8 hours, 150% of peak load	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	8 hours, 150% of peak load	4 hours, 25% of peak load	4 hours, 25% of peak load
		CT02	**24214**	**K**	**46**	**50**	**No**	**1.1**	8 hours, 150% of peak load	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	8 hours, 150% of peak load	4 hours, 25% of peak load	4 hours, 25% of peak load
Hawkeye Energy Greenport LLC	**55969**	**U-01**	**23814**	**K**	**60**	**54**	**No**	**1.1**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
Equus Freeport Power	**56032**	**0001**	**23764**	**K**	**51**	**60**	**No**	**2.3**	None	None	None
								-	None	None	None
Wading River	**7146**	**UGT007**	**23522**	**K**	**95**	**79.5**	**No**	**1.1**	8 hours, 150% of peak load	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	8 hours, 150% of peak load
		UGT008	**23547**	**K**	**93**	**79.5**	**No**	**1.1**	8 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 25% of peak load
								-	8 hours, 150% of peak load	4 hours, 100% of peak load	4 hours, 25% of peak load
		UGT009	**23601**	**K**	**93**	**79.5**	**No**	**1.1**	8 hours, 150% of peak load	8 hours, 150% of peak load	8 hours, 150% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	8 hours, 150% of peak load
		UGT013	**23715**	**K**	**60**	**52.9**	**No**	**1.1**	6 hours, 125% of peak load	4 hours, 125% of peak load	4 hours, 100% of peak load
								-	6 hours, 125% of peak load	4 hours, 125% of peak load	6 hours, 75% of peak load
		UGT014	**23716**	**K**	**21**	**18.6**	**No**	**1.1**	4 hours, 150% of peak load	8 hours, 75% of peak load	4 hours, 125% of peak load
								-	4 hours, 150% of peak load	8 hours, 75% of peak load	4 hours, 125% of peak load
Glenwood Landing	**7869**	**UGT011**	**23712**	**K**	**15**	**16**	**No**	**1.2**	4 hours, 125% of peak load	6 hours, 75% of peak load	6 hours, 75% of peak load
								-	4 hours, 125% of peak load	8 hours, 75% of peak load	6 hours, 75% of peak load
		UGT012	**24219**	**K**	**46**	**53**	**No**	**1.2**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
		UGT013	**24220**	**K**	**47**	**53**	**No**	**1.2**	None	None	None
								-	None	None	None
Vernon Boulevard	**7909**	**VB01**	**24162**	**J**	**45**	**47**	**No**	**4**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
		VB02	**24163**	**J**	**44**	**47**	**No**	**4**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
Joseph J Seymour Power Project	**7910**	**2301**	**24156**	**J**	**45**	**47**	**No**	**4.2**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
		2302	**24157**	**J**	**50**	**47**	**No**	**4.2**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
Brentwood	**7912**	**BW01**	**24164**	**K**	**49**	**47**	**No**	**0.6**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	4 hours, 25% of peak load	4 hours, 25% of peak load
Hell Gate	**7913**	**HG01**	**24158**	**J**	**49**	**47**	**No**	**2.9**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
		HG02	**24159**	**J**	**49**	**47**	**No**	**2.9**	None	4 hours, 25% of peak load	4 hours, 25% of peak load

								-	None	None	None
Harlem River Yard	**7914**	**HR01**	**24160**	**J**	**48**	**47**	**No**	**2.9**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
		HR02	**24161**	**J**	**47**	**47**	**No**	**2.9**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
North 1st	**7915**	**NO1**	**24152**	**J**	**49**	**47**	**No**	**6.3**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
Holtsville	**8007**	**U1**	**23690**	**K**	**53**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
								-	8 hours, 125% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
		U10	**23699**	**K**	**50**	**56.7**	**No**	**1.1**	8 hours, 150% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	6 hours, 150% of peak load	8 hours, 100% of peak load
		U2	**23691**	**K**	**53**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
								-	8 hours, 125% of peak load	8 hours, 125% of peak load	6 hours, 150% of peak load
		U3	**23692**	**K**	**48**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U4	**23693**	**K**	**48**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U5	**23694**	**K**	**51**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	8 hours, 100% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U6	**23695**	**K**	**51**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	8 hours, 100% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U7	**23696**	**K**	**51**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U8	**23697**	**K**	**51**	**56.7**	**No**	**1.1**	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 125% of peak load	6 hours, 150% of peak load	6 hours, 125% of peak load
		U9	**23698**	**K**	**50**	**56.7**	**No**	**1.1**	8 hours, 150% of peak load	6 hours, 150% of peak load	8 hours, 100% of peak load
								-	8 hours, 150% of peak load	8 hours, 125% of peak load	8 hours, 100% of peak load
Pouch	**8053**	**PT01**	**24155**	**J**	**49**	**47**	**No**	**2.7**	None	4 hours, 25% of peak load	4 hours, 25% of peak load
								-	None	None	None
Astoria Generating Station	**8906**	**CT0001**	**23523**	**J**	**20**	**15**	**Yes**	**3**	8 hours, 150% of peak load	8 hours, 150% of peak load	6 hours, 125% of peak load
								-	8 hours, 150% of peak load	8 hours, 150% of peak load	8 hours, 150% of peak load

Appendix C: Full Reliability Study Description

Resource adequacy is a critical concern especially in systems such as New York City and Long Island that have high reliability value and that are already constrained by existing transmission and generation limitations.

As systems transition from primarily thermal resources to ones with more renewables, storage and demand response (DR) resources, determining resource adequacy and reliability needs becomes more complex. This means existing rules of thumb, methodologies and models need to be updated or replaced with ones that are more suited to determining the reliability needs of the future system. For more decarbonized systems, reliability hinges on renewable availability, which is weather dependent, while storage and demand response availability depends on multiple factors.

For renewables, storage, and demand-side resources, there are both saturation and interactive effects that must be accounted for which makes a generic rule of thumb difficult to apply to a particular resource without knowing the installed quantity of that resource or other resources on the system. In order to ensure that a system has adequate resources, a model that is capable of calculating the capacity value and reliability contribution of these resources that can account for both the diminishing saturation effects of resources as well as the interactive effects between different resources should be used.

Analytical tools used for reliability planning capture thermal resource and transmission forced outages and these tools are being expanded to include more time-sequential approaches that better account for variability of renewables and correlations to load as well as better tracking of hydro and storage state-of-charge. These time-sequential approaches to reliability can better capture the energy-limited aspect of storage and demand response resources in the following manner:

- State-of-charge (storage) and number of calls (DR) can be tracked, limiting the availability of shorter-duration storage and limited-call DR resources
- Storage/DR dispatch would only discharge for reliability when all other resources are not sufficient; storage would charge at the first available opportunity
- Storage/DR capacity and reliability value should be quantified endogenously, recalculating dispatch and charging schedules according to system needs and availability. This means system conditions can affect capacity and reliability value, e.g. more renewables tend to increase capacity value of storage due to synergistic effects of peakier reliability needs that are more well suited to being met with storage

Separate from the approach described above, the NYISO conducts long-term planning analysis through its Reliability Planning Process as part of its Comprehensive System Planning Process

(CSPP).[38] Con Edison/ LIPA also have contingency planning methods to ensure reliability criteria are maintained. These studies include the NYISO's Reliability Needs Assessments, Comprehensive Reliability Plans, Generator Deactivation Assessments, and Interconnection processes. As the mix of resources interconnected to the electric grid changes, it will be important to evaluate prevailing reliability assessment methodologies to ensure the contribution of energy storage and renewables to grid reliability is properly considered.

[38] More information on the NYISO's Comprehensive System Planning Process and Reliability Planning Process can found at: https://www.nyiso.com/planning and https://www.nyiso.com/documents/20142/2924447/rpp_mnl.pdf/85b28e6b-16b0-0ce7-60f3-c2291733acea.

Appendix D: Peaker Analysis from New York Storage Roadmap

As part of the Roadmap, E3 performed a high-level screening analysis of downstate (Zone J and Zone K) peakers to determine whether any units had characteristics that would make them potential candidates for repowering and/or replacement with energy storage systems. This analysis examined the operational profiles of these units based on 2015-17 generation data from three sources:[39]

- **NYISO Planning Documents** for 2017 NYCA Generation Facilities, which included Unit Name, Zone, Location, In-Service Date, Summer and Winter Capacity, Unit Type and Fuel types
- **EPA Air Markets Program Data** for 2015-2017, which included:
  - Unit-by-Unit hourly data for generation, operating time, CO_2, SO_2, and NO_x, emissions[40]
  - Facility-level data for Location, Owner, Operator, Unit type, Fuel types, Commercial Operation Date and Pollutant controls
- **SNL Financial (S&P Market Intelligence)** for 2015-17, which included Unit-by-unit data for Fuel Costs, Total O&M, Fixed Costs, and Heat Rates.

The analysis was done from a purely *ex post* operational screening perspective. No consideration was given to contracting and financial arrangements, nor to reliability planning or local reserve requirements that may apply to individual facilities and/or specific units. While data coverage for this analysis was not 100 percent, it did yield several useful insights.

Operational Analysis

The first step of the screening methodology was to separate peaking units into three groups based on their respective operational characteristics:

- **Group 1:** Peaking units that never run more than 4 hours per start[41]
- **Group 2:** Peaking units that average less than 4 hours per start but may run more than 4 hours[42]
- **Group 3:** Peaking units that always run more than 4 hours[43]

---

[39] The data extraction methodology was as follows:

- Extract list of 2017 NYCA candidate generators which are existing peakers and steam turbines (ST) in Zones J & K
- Match units from NYISO generator data with EPA Facility data using name, in-service date, unit type, and capacity
- Extract hourly unit-level operations and emissions data from EPA dataset
- Calculate unit-by-unit: Hours of operation, # Starts, Hours of operations / start, Distribution of the duration of starts, # and % of starts with durations greater than 4 hours, Capacity factor, Age, Emission intensity
- Match unit-level S&P Market Intelligence data to determine Fuel Costs ($/MWh), Total O&M ($/MWh) and heat rates (btu/kWh)

[40] Note that this dataset is incomplete: for a subset of units, operation data is only reported from April to September and does not include CO_2 or SO_2 emissions.

[41] These are units like the ones in the Gowanus and Astoria facilities.

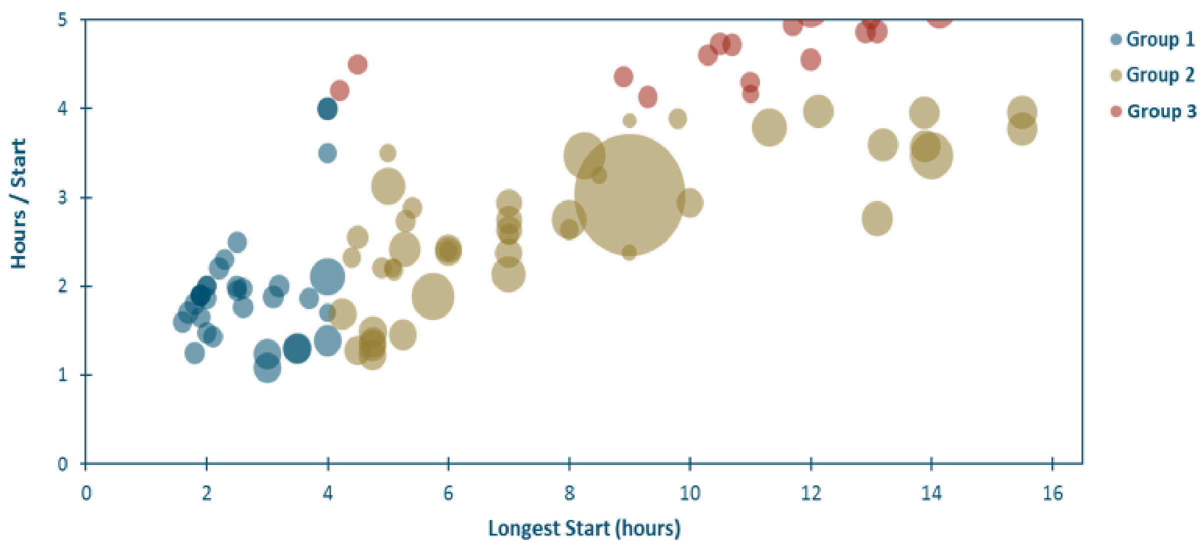
[42] These are units like the ones in the Ravenswood, Gowanus, and Astoria facilities.

[43] These are units like the ones in the Bayonne and Narrows facilities.

The analysis then compared different metrics of each group across years and looked at whether units operate at concurrent time periods. Large facilities were analyzed by aggregating their individual units into the appropriate group.

The figure below illustrates Hours per Start and Longest Start for Group 1, 2, and 3 peaking units, using 2017 data where the size of the bubbles represents the MWs of the peaking units:

Figure D1. Hours per Start and Longest Start for Group 1, 2, and 3 Peaking Units



The **average characteristics** of Group 1 and 2 peaking units, based on 2017 data, were as follows[44]:

Table D1. Average Characteristics for Group 1 and 2 Peaking Units (2017)

Group	Total MW	# of Units	Avg. Unit Age	Capacity (MW)	CF (%)	# Starts	# of Hours per start	Longest Start (hrs)	NOx Emissions (lb/MWh)	Est. Fuel Costs ($/MWh)	Est. Total O&M ($/MWh)
1	708	34	47.5	20.8	0.2%	10.9	2.0	2.7	6.9	131.6	674.6
2	2,002	45	40.0	44.5	1.4%	43.4	2.7	7.8	5.3	88.0	227.5

[44] Group 3 is not included because the focus of this analysis was Groups 1 and 2.

Analysis showed that these characteristics vary across years, as shown in the following tables based on 2016 and 2015 data, respectively:

Table D2. Average Characteristics for Group 1 and 2 Peaking Units (2016)

Group	Total MW	# of Units	Avg. Unit Age	Capacity (MW)	CF (%)	# Starts	# of Hours per start	Longest Start (hrs)	NOx Emissions (lb/MWh)	Est. Fuel Costs ($/MWh)	Est. Total O&M ($/MWh)
1	301	18	47.3	16.7	0.2%	5.1	1.8	2.7	8.0	191.1	1151.2
2	1,539	55	45.3	28.0	1.2%	33.3	3.0	9.6	5.6	88.5	278.4

Table D3. Average Characteristics for Group 1 and 2 Peaking Units (2015)

Group	Total MW	# of Units	Avg. Unit Age	Capacity (MW)	CF (%)	# Starts	# of Hours per start	Longest Start (hrs)	NOx Emissions (lb/MWh)	Est. Fuel Costs ($/MWh)	Est. Total O&M ($/MWh)
1	388	21	47.3	18.5	0.1%	4.0	1.7	2.2	7.1	198.2	940.4
2	2,089	55	45.4	38.0	0.9%	33.9	2.6	8.8	6.3	93.3	338.1

Overall **fleet characteristics** for Groups 1, 2, and 3 peaking units were calculated as follows (note that NO_x, CO_2 and SO_2 emissions are weighted average emissions rates):

Table D4. Downstate Peaking Units: Overall Characteristics Based on 2017 Data[45]

Group	# of Units	Age	Total Capacity (MW)	Avg Unit Size (MW)	CF (%)	# of Hours per start	Avg Longest Start (hrs)	NOx Emissions (lb/MWh)	CO2 Emissions (tons/MWh)	SO2 Emissions (lb/MWh)
1	34	47.5	708	20.8	0.2%	2.0	2.7	4.594	0.587	0.083
2	45	40.0	2,002	44.5	1.4%	2.7	7.8	2.474	0.659	0.017
3	47	29.3	1,858	39.5	8.6%	5.6	19.9	0.627	0.572	0.006

Similarly, **operation data**[46] from Groups 1, 2, and 3 units were as follows:

[45] 2017 is not necessarily a representative year from a meteorology perspective and the fleet characteristics may change year to year.

[46] This was based on hourly data to the extent possible.

Table D5. Downstate Peaking Units: Operation Data

Group	Summer Gen (MWh)	Summer NOx (lb)	Summer CO2* (tons)	Summer SO2 (lb)	Total Gen** (MWh)	Total NOx** (lb)	Total CO2* (tons)	Total SO2* (lb)
1	10,270	47,798	6,076	309	18,922	86,924	11,113	1,574
2	144,149	302,576	95,690	1,310	214,923	531,664	141,754	3,751
3	1,138,329	693,723	661,713	6,283	1,777,062	1,114,513	1,015,620	9,855

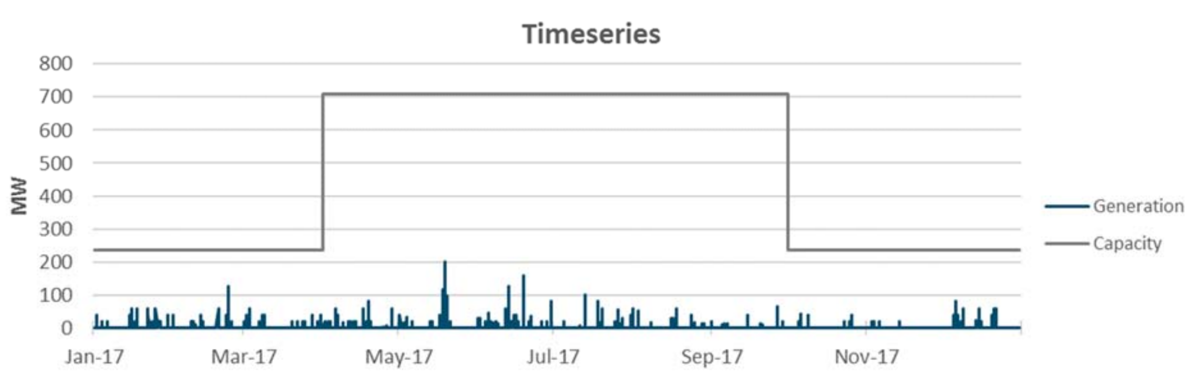
** CO_2 & SO_2 values were estimated with the group average emission factor for units that do not report data*
*** For units that do not report winter data, totals were estimated using summer capacity factor*

Three important **caveats** related to limitations in the Environmental Protection Agency (EPA) dataset must be made. Several units in this dataset – predominantly Group 1 units, characterized by small units with very low capacity factors that typically burn oil in the winter – only report data for the SIP NOx program. This program only includes data from April 1 through September 30 for generation and NOx emissions and does not include data for CO_2 or SO_2 emissions. Consequently:

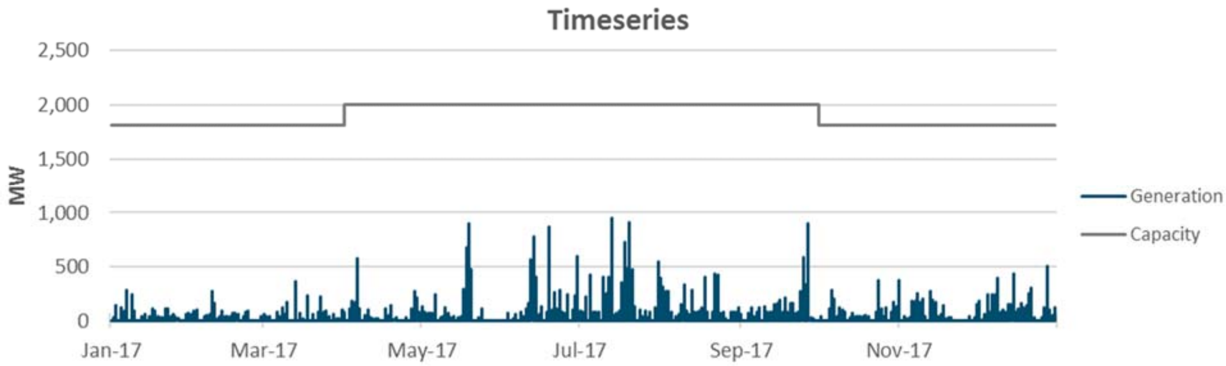
- **Group 1 units' emission rates and total emissions may be understated**. This is due to understating the amount or relative share of oil burnt to natural gas given that oil is more carbon- and SO_2-intensive than natural gas.
- **Group 1 units' total generation may be slightly overestimated** since peakers seem to run slightly more during the summer than during the winter.
- **There is substantially more uncertainty in the estimates of Group 1 fleet characteristics** (e.g., hours/start, capacity factors, emission rates, etc.) relative to Group 2.

Analysis showed that peaking units that may be candidates for energy storage hybridization, replacement, or repowering (those in Groups 1 and 2) did not seem to operate near capacity at any point in 2017. They do, however, appear to have operated concurrently during a few scarcity periods, particularly in the summer months and in December:

Group 1



Group 2



As shown in the following graphic, the locations of Group 1 and Group 2 peaking units (shown as dropped pins) are highly correlated with Environmental Justice (EJ) areas (highlighted in purple), particularly near New York City:

Finally, the analysis also developed **high-level 2017 revenue estimates** for peaker units in Groups 1, 2, and 3. The methodology here involved developing NYISO market revenue estimates for peaker fleets, and then utilizing publicly available monthly ICAP prices and LBMPs for individual peakers. Note that this analysis does not account for uplift payments or other payments (e.g., startup costs) for units operating for local reliability in an out of merit order dispatch. The 2017 economics of peaking units were found to be as follows.

Table D6. Downstate Peaking Units: Revenue Estimates (2017)

Group	Zone	ICAP Revenues[1]	Energy Revenues[2]	Fuel O&M[2]	Total O&M[2]	Profits[2]	Profits[3] ($/kW-yr)
1	J	$ 56,930,557	$ 1,329,050	$ 1,167,011	$ 4,466,504	$ 53,793,102	**$ 83.49**
	K	$ 2,690,250	$ 80,215	$ 192,383	$ 608,174	$ 2,162,291	**$ 34.05**
2	J	$ 70,283,942	$ 10,186,056	$ 5,530,799	$ 13,444,249	$ 67,025,749	**$ 83.28**
	K	$ 50,660,202	$ 7,797,749	$ 6,921,433	$ 13,065,499	$ 45,392,452	**$ 37.90**
3	J	$ 92,971,144	$ 53,086,648	$ 35,554,043	$ 45,384,867	$ 100,672,925	**$ 92.03**
	K	$ 32,127,144	$ 41,377,071	$ 28,729,124	$ 35,158,194	$ 38,346,021	**$ 50.19**

[1] ICAP revenues assumes that all the summer and winter capacity is under contract at average price
[2] For units that do not report Winter data, totals are estimated using Summer capacity factor
[3] Profits = (ICAP + Energy Revenues) – Total O&M

The key takeaways from this analysis are summarized in Section 4.6 of the Roadmap. This analysis did not consider local reliability requirements where these facilities may be considered for meeting contingency needs.

Appendix E: Additional Results

Table E1. Hybridization candidates to meet 2023 limit under various storage sizing assumptions, $100 congestion threshold

Capacity (% of 2013 peak)	Hours	Number of units	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
25	4	11	601	13%	263	75,313	17,453	2	4
	6	12	626	14%	242	104,516	24,250	4	4
	8	12	626	14%	242	127,233	28,795	4	4
50	4	12	626	14%	242	149,523	35,413	4	5
	6	15	754	17%	195	208,776	62,956	5	5
	8	15	754	17%	195	253,736	72,697	5	5
75	4	19	828	18%	155	225,417	74,078	5	5
	6	26	1,004	22%	115	317,095	157,074	6	6
	8	41	1,557	35%	77	442,098	575,157	13	13
100	4	25	957	21%	119	298,863	136,387	7	8
	6	43	1,622	36%	74	481,485	691,928	14	15
	8	62	2,323	52%	55	658,341	1,623,028	20	20

Table E2. Hybridization candidates to meet 2023 limit under various storage sizing assumptions paired with solar, $100 congestion threshold

Capacity (% of 2013 peak)	Hours	Number of units	Aggregate nameplate capacity (MW)	Percent of total nameplate capacity	Average longest start (hours)	Total avoided MWh of peaker generation	Total avoided NOx emissions (lb)	Average avoided NOx non-compliance days in 2023	Average avoided NOx non-compliance days in 2025
25	4	24	1,229	27%	150	176,119	37,209	4	5
	6	25	1,247	28%	144	228,879	48,342	5	5
	8	25	1,247	28%	144	268,868	56,040	5	5
50	4	27	1,280	29%	134	324,990	73,355	5	6
	6	30	1,406	31%	121	430,210	109,201	5	6
	8	32	1,450	32%	114	510,890	130,545	5	7
75	4	33	1,463	33%	110	472,670	124,190	5	6
	6	43	1,704	38%	87	640,223	259,004	7	8
	8	60	2,316	52%	65	817,940	712,389	12	12
100	4	41	1,698	38%	91	615,977	246,618	7	8
	6	62	2,382	53%	63	878,454	804,627	12	12
	8	82	3,107	69%	52	1,149,718	1,991,323	19	19