Pterra Report R161-20

Study of Transmission Alternatives to Interconnect 9000 MW of Offshore Wind Generation in New York

Appendix B to Offshore Wind Transmission: An Analysis of Options for New York

Submitted to

Anbaric Development Partners

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Executive Summary

Pterra, LLC ("Pterra") was contracted by Anbaric Development Partners ("ADP") to conduct a study of different configurations to interconnect 9000 MW of offshore wind ("OSW") generation in the New York Control Area ("NYCA"). The interconnection method considered was via generator leads and shared radial systems.

The study comprised of the following analyses: (a) solo injection – measuring the injection capability for OSW at selected points of interconnection (POI) with no other OSW in service, (b) considering larger sized OSW interconnections, and (c) OSW development sequence – determining transmission upgrade requirements for various paths to reach 9000 MW of OSW.

The base case power flow models used in this study were requested from the NYISO as part of its FERC 715 filing. The study evaluated the impact of OSW on the NYCA in the New York City (Zone J) and Long Island (Zone K) regions for facilities rated 69 kV and higher. The power plants at Port Jefferson and Narrows were assumed to have been retired by the year 2035. The Barrett power plant was considered under two scenarios: first, as a plant due for retirement, and second, as a plant due for repowering. Steady-state power flow solution and contingency analysis were used to determine the thermal impact of the OSW injection on the underlying alternating-current (AC) system. The analysis was performed using PowerGEM's Transmission Adequacy and Reliability Assessment (TARA) software. The security-constrained redispatch (SCD) function of TARA was utilized in performing the analysis in addition to normal AC contingency analysis. For the SCD, no reliability must-run generators were designated. Deliverability assessment was likewise conducted using TARA. Generation production simulations were performed with ABB-Hitachi's Gridview software.

Results presented in this report are based on the thermal capacity of the existing and planned NYCA. Further analysis will be needed to address other reliability and operations aspects of the grid including stability, fault withstand, other forms of contingencies (including n-1-1) and extreme events, torsional interactions, power quality, reserve requirements, among others.

Solo Injection Analysis

For the solo injection[1] analysis, ADP identified several potential POIs for future OSW. These are shown in Figure S- 1.

OSWs were evaluated for maximum injection capacity with only the following other OSW plants in service:

- 800 MW Equinor Gowanus (NYISO queue Q737
- 880 MW Ørsted Holbrook
- 136 MW Q695 Deepwater Wind Farm

[1] Solo injection refers to the capacity to interconnect OSW MW as an energy resource for the grid with no other new generation, including other OSW, interconnecting, except where noted. Solo injection capacities are based only on thermal first contingency considerations.

Figure S- 1: Potential Points of Interconnection for Offshore Wind Generation

In Eastern Long Island, the solo injection capacities range from 250-650 MW, with the highest value identified at Brookhaven. Central Long Island is the main load pocket for Zone K. OSW POIs at 138 kV in this zone show injection capacities in the range of 1,350-1,800 MW. The highest injection capacity among which is at Holbrook. For the two 69 kV POIs tested in this zone, Brightwaters and Brentwood, both showed zero injection capacity. This is due to local constraints on the 69 kV system. For Western Long Island, injection at Valley Stream is limited to 400 MW. At Barrett, there is no injection capacity if Barrett is not retired. If Barrett is retired, the OSW injection capacity is 400 MW. If Barrett is repowered, this capacity is reduced to 50 MW.

For New York City, the OSW POIs on Manhattan island deliver directly to a large load pocket. For no SUFs[2], the resulting solo injection capacities are 1,850 and 1,450 MW, respectively for West 49th St and East 13th St. Likewise, the OSW POIs in Brooklyn and Queens have a large load pocket to deliver to. This results in injection capacities of 1,800-2,500 for 345 kV POI, and 450-1,400 MW for 138 kV POIs. The largest solo injection capacity is at Gowanus. The Staten Island OSW POI injection results show capacities in the range of 500-1,550 MW, with the larger capacity associated with the higher voltage POIs.

Notes on the solo injection analysis:

- The solo POI injection capacities are not necessarily additive, i.e., if POI A has a capacity of 100 MW and POI B has 150 MW, developing both POIs A and B does not necessarily mean there is a total of 250 MW injection capacity. If POIs A and B are near each other such that they may share use of certain elements of the transmission grid then their combined capacity will tend to be less than the sum of their individual capacities as they jointly utilize the shared transmission facilities.
- Effects of combining OSW POIs:
    - Any two POIs in Zones J and K interconnecting at their maximum solo injection capacity results in a reduction of their combined injection capacity by 8 to 12%.

2 SUF – system upgrade facilities. These are facilities such as new or upgraded transmission lines and transformers which the existing grid needs to support the full energy injected by the OSW plant.

- However, when the POIs are in close proximity such as Ruland Rd/Holbrook and Gowanus/Fresh Kills, there is a larger reduction in combined capacity due to the common use of nearby transmission elements.

Considering larger sized OSW interconnections

Two options were considered (1) Increasing the POIs with solo injection capacity below 600 MW to 1200 MW via transmission upgrades and (2) Increasing the POIs with solo injection capacity over 1150 MW to 2000 MW via transmission upgrades.

For the first option, three POIs were considered for this analysis: Hudson, Fox Hill and Valley Stream. All these POIS have solo injection capacities below 600 MW. In order to increase their injection capacity to 1200 MW, each of the POIs will require a number of SUFs.

For the second option, POIs with solo injection capacity of at least 1,150 MW were tested for an injection of 2,000 MW. Of the POIs considered, Gowanus had a solo injection capacity greater than 2,000 MW even without SUFs.

OSW development sequences

Using the results of the solo injection analysis, interactions between injections, and evaluation of larger injections as a guide and applying knowledge gained from each stage of the study resulted in a number of proposed development sequences. In all these sequences, the Equinor Gowanus, Ørsted Holbrook and Deepwater projects are assumed to be firm projects and thus comprise the front end of any OSW development sequence.

Upgrade costs

As each OSW project is developed in a sequence, analyses to identify System Upgrade Facilities (SUFs) for Energy Resource Interconnection Service (ERIS) and System Deliverability Upgrades (SDUs) for Capacity Resource Interconnection Service (CRIS) were conducted. The costs for implementing the SUFs and SDUs were initially estimated using P50 pro forma prices.

> *Addendum from ADP:*
>
> *Further analysis was then conducted by PSC Consulting to determine installed costs. PSC Consulting analyzed system upgrades using system one-line diagrams, aerial photographs, and other available information to determine major equipment quantities needed to construct the upgrades. Direct construction costs were calculated from the major equipment quantities and unit costs. Escalation factors for project management, mobilization, de-mobilization, engineering, permitting, commissioning, administrative, general overhead, and contingencies were applied to determine total upgrade costs. The total upgrade costs are provided with an accuracy range to account for unpredictability in scope definition, raw material cost variations, and other discrepancies within the estimate.*
>
> *The installation and material unit cost of the major equipment along with the appropriate escalation factors were derived from a variety of sources including publicly available project costs, industry standard costing guides, utility experience, and industry practice. Additionally, unit costs have been adjusted to reflect the local labor market and assumed site conditions.*
>
> *Cost estimates do not include property acquisition, 3rd party payments such as community benefit or other compensation, unforeseen site conditions such as poor soil conditions or environmental remediation, taxes, AFUDC, or other unrelated costs.*

Planned OSW Sequence

Of the various OSW development sequences studied, a sequence based on a planned approach to OSW development resulted in the lowest total cost of SUFs and SDUs, at $359 million to $673 million. The sequence and associated upgrades are shown in Table S-2**Error! Reference source not found.**.

Production simulation was conducted to determine the performance of the energy supply system as OSW is introduced into the NYISO grid. The simulations were conducted using the GridView software, which analyzes sequential 8760-hour of system operations. No must-run units in New York and Long Island were assumed in the simulations. The OSW capacity factors for years 2026 and 2035 are shown in Table S- 1**Error! Reference source not found.**. In 2026, OSW can operate at or near their rated capacity factor of 51.4%. In 2035, there are reductions in the capacity factors for the OSW interconnected at Gowanus and Fresh Kills. These are due to transmission constraints on the outlet of the injected power from the OSW. The constraints are not identified under the Minimum Interconnection and Minimum Deliverability Standards because they occur at off-peak hours of the winter and spring seasons.

To increase the capacity factor for the Gowanus OSW, a transmission upgrade, classified as an Optional Upgrade, was considered. A new 345 kV line from Gowanus to Rainey results in an increase of the Gowanus OSW capacity factor to 47.3%. The energy supply mix for the New York City and Long Island Zones in 2035 is depicted in Figure S- 2.

Table S- 1: Capacity Factors for OSW for Planned OSW Sequence

Sequence	POI	Year 2026	Year 2035	Year 2035 with Optional Upgrades
1, 2 and 3	Ørsted Holbrook	51.4%	51.2%	51.2%
	Deepwater	51.4%	50.3%	50.3%
	Equinor Gowanus	51.4%	40.0%	47.3%
4	Rainey	51.4%	51.4%	51.4%
5	Ruland Rd	51.3%	51.2%	51.2%
6	Gowanus	-	40.0%	47.3%
7	East Garden City	-	49.6%	49.6%
8	Fresh Kills	-	21.6%	18.7%

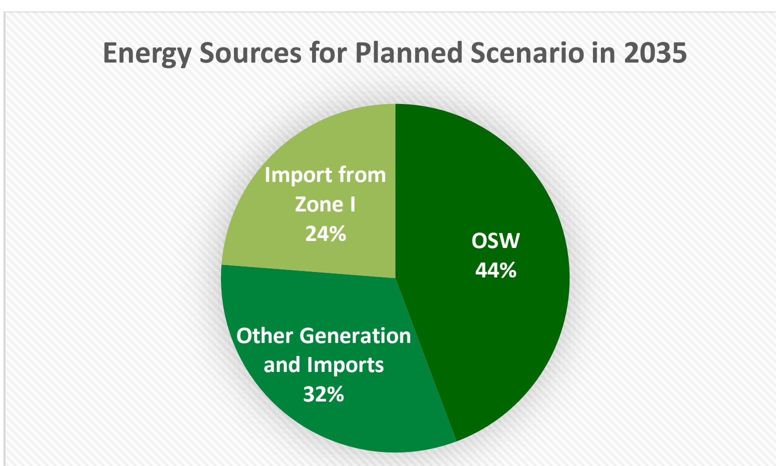

Figure S- 2: Zone J and K Energy Sources with No Optional Upgrades in 2035

Table S- 2: Planned OSW Development Sequence

Sequence	POI	Sub-Zone	MW	Loca-tion	System Upgrade Facilities	System Deliverability Upgrades	Total Cost of Upgrades ($M)[3]		
							Low	High	Midpoint
1, 2 and 3	Ørsted Holbrook	Central Long Island	880	LI	None	None			-
	Deepwater	Eastern Long Island	136	LI	None	None			-
	Equinor Gowanus	Brooklyn	800	NYC	None	None			-
4	Rainey	Brooklyn	1200	NYC	None	Two additional 345/138 kV transformers at Rainey; two additional 138 kV lines Rainey-Vernon	$81.4	$152.6	$117.0
5	Ruland Rd	Central Long Island	1200	LI	345 kV interconnection with link to Newbridge	None	$54.5	$102.3	$78.4
6	Gowanus	Brooklyn	2000	NYC	None	None[4]			
7	East Garden City	Central Long Island	1100	LI	Valley Stream-East Garden City 138 kV	None	$67.7	$126.9	$97.3
8	Fresh Kills	Staten Island	1700	NYC	Additional circuits: Fresh Kills-Goethals 345; Goethals-Gowanus 345 kV	None	$155.3	$291.2	$223.3
Totals			9016				*$358.9*	*$673.0*	*$516.0*

3 Estimates prepared by PSC Consulting.
4 Deliverability testing procedure did not show an upgrade need although subsequent production simulation determines that an optional upgrade of a new Gowanus-Rainey 345 kV line will increase the delivered capacity factor of the Gowanus OSW.

Table S- 3: Unplanned OSW Development Sequence

Sequence	POI	Sub-Zone	MW	Loc a-tion	System Upgrade Facilities	System Deliverability Upgrades	Total Cost of Upgrades ($M)		
							Low	High	Midpoint
1, 2 and 3	Ørsted Holbrook	Central Long Island	880	LI	None	None			-
	Deepwater	Eastern Long Island	136	LI	None	None			-
	Equinor Gowanus	Brooklyn	800	NYC	None	None			-
4	Fresh Kills	Staten Island	800	NYC	None	Gowanus-Goethals 345	$128.6	$241.1	$184.9
5	Gowanus	Brooklyn	800	NYC	None	Gowanus-Rainey 345 kV line; two additional 345/138 kV transformers at Rainey; two additional 138 kV lines Rainey-Vernon	$324.7	$608.9	$466.8
6	Holbrook	Central Long Island	800	LI	None	None			
7	Ruland Rd	Central Long Island	1200	LI	345 kV interconnection with link to Newbridge	None	$54.5	$102.3	$78.4
8	East Garden City	Central Long Island	1200	LI	None	None			
9	Brook-haven	Eastern Long Island	1200	LI	Brookhaven-Sills Rd 138 (3); Haupague-Pilgrim 138 (1)	None	$345.8	$648.3	$497.1
10	Barrett	Western Long Island	1184	LI	Barrett-Valley Stream 138 (5); Valley Stream-EGC 138 (3)	None	$540.2	$1,012.8	$776.5
Totals			9000				*$1,393.8*	*$2,613.4*	*$2,003.6*

Unplanned OSW Sequence

An unplanned OSW development sequence results in total upgrade costs of $1.39 billion to $2.61 billion. Such a sequence is shown in Table S- 3.

Capacity factors for the OSW range from 47.8% to 51.4% in 2026. The capacity factors are lower in 2035 with 22.4%, 37.4% and 37.6% for the East Garden City, Brookhaven and Deepwater OSW injections, respectively.

Optional upgrades comprising of a new Holbrook-Ruland Rd 138 kV line and a new Dunwoodie-Shore Rd cable can increase the capacity factors for East Garden City and Holbrook OSW but, overall, will require further optional upgrades to bring the overall OSW capacity factor near 50%.

Table S- 4: Capacity Factors for OSW for Unplanned OSW Sequence

Sequence	POI	Year 2026	Year 2035	Year 2035 with Optional Upgrades
1, 2 and 3	Ørsted Holbrook	47.8%	39.7%	44.8%
	Deepwater	51.4%	37.6%	37.2%
	Equinor Gowanus	51.4%	51.4%	51.3%
4	Freshkills	47.8%	49.0%	49.1%
5	Gowanus	51.4%	51.4%	51.3%
6	Holbrook	47.8%	39.7%	44.8%
7	Ruland Rd		49.4%	47.1%
8	East Garden City		22.4%	35.2%
9	Brookhaven		37.4%	34.8%
10	Barrett		46.0%	47.4%

Section 1. Introduction

Pterra, LLC ("Pterra") was contracted by Anbaric Development Partners ("ADP") to conduct a transmission study to interconnection of 9000 MW of offshore wind ("OSW") generation in the New York Control Area ("NYCA"). The interconnection method considered was via generator leads and shared radials.

1.1. Objective

The aim of this study is to identify transmission upgrades in the NYCA operated by the New York Independent System Operator ("NYISO") that can support 9000 MW of offshore wind generation in New York.

1.2. Scope of Services

The tasks performed by Pterra for this study are:

1. **Solo Injection Analysis:** A set of power flow models were developed for a set of potential points of interconnection (POI) for future OSW in New York. For each POI, Pterra studied the summer peak injection capacity, assuming Equinor Gowanus 800 MW, Ørsted Holbrook 880 MW and Deepwater (now Ørsted) Q695 Deepwater Wind Farm at East Hampton 69 kV for 136 MW are already in service. The injection analysis considered n-0 and n-1 thermal conditions only.

   In addition, sensitivity tests were conducted for:

   - Solo injection with an additional system upgrade facility (SUF) – to identify POIs where an SUF may be cost-effective in increasing the injection capacity
   - Combination injection – to identify how various POIs in tandem impact their combined injection capacity
   - Solo Injection with a new submarine cable between ConEd and Long Island
   - Solo injection with new transmission connection between ConEd and Long Island

2. **Evaluate OSW Development Sequences.** Potential sequences for implementation of OSW projects in New York leading up to 9000 MW are developed using knowledge gained from the solo injection analysis and cable routing constraints. For each sequence, the following aspects were studied:

   a. **Energy Resource Interconnection Service (ERIS) Upgrades Analyses:** The individual OSW in a sequence are studied for ERIS interconnection requirements. This analysis replicated the thermal loading aspects of the NYISO system reliability impact study (SRIS), in accordance with NYISO Minimum Interconnection Standard (MIS) OATT 25.2.

      The analyses for n-0 and n-1 thermal performance were conducted for summer peak, winter peak and light load conditions.

   b. **Capacity Resource Interconnection Service (CRIS) Upgrades Analyses:** For each of the development sequences, a deliverability study was conducted to identify transmission upgrades in accordance with OATT 25.3. The deliverability performance was tested at summer peak conditions applying the NYISO Deliverability Interconnection Standard (DIS).

c. **Production Simulation:** For two selected development sequences, 8760-hour simulations of energy production costs were conducted to show how OSW fits in a load duration curve and how much wind actually gets dispatched due to seasonal variations. Specifically, using the 8760 OSW output (scaled to 9,000 MW) earlier provided by Anbaric, and additional transmission upgrades were run against actual load & imports/exports.

3. **Evaluate Potential for Larger Sized OSW Interconnections.** For a selected set of POIs, the upgrade requirements to enable interconnection of 2000 and 1200 MW OSW projects were evaluated. The potential for interconnecting OSW to new dedicated substation is also evaluated.

Based on the results, two representative development sequences were identified to 1) reflect a planned approach to maximize overall utilization of POIs and cable access routes and 2) reflect potential outcomes of the current approach of developing each project individually and sequentially.

1.3. This Report

This report comprises of the following sections:

- Study Data and Assumptions
- Solo Injection Analysis
- Individual OSW Sequence of Development
- Conclusions

Section 2. Study Data and Assumptions

This section documents the study data, and simplifying assumptions used to conduct the study.

2.1. Study Cases

The base case power flow model used in this study was requested from the New York Independent System Operator (NYISO) as part of the FERC 715 filing. The available power flow model applicable to this study is the year 2027.

The study cases were modified to include: the 2nd Valley Stream to East Garden City cable and a third transformer at Newbridge.

Pterra created contingencies for facilities rated 69 kV and higher covering zone I to zone K based on the design contingencies applied by NYISO in interconnection studies. These were applied in the study in order to determine any thermal impacts.

2.2. Study Area

The study evaluated the impact of OSW on the New York State Bulk Power System ("NYSBPS") in the ConEd (Zone J) and PSEGLI (Zone K) regions for facilities rated 69 kV and higher. With the system intact, the continuous or normal rating (RATE A) was applied. For post contingencies, applicable short-term emergency (STE, or Rate C) ratings were applied for underground cables within the ConEd transmission system as specified by NYISO, while long-term emergency (LTE, or Rate B) ratings were applied to the other branch facilities.

2.3. Load Forecast

According to the NYISO 2018 Gold Book Report, the forecast for 90/10 summer peak load growth does not exceed 0.3% over the next 15 years. Pterra applied no load changes to the power flow models as this amount of load growth would have minimal effect in developing the transmission plan for OSW integration.

2.4. Generation Retirements

The power plants at Port Jefferson and Narrows were assumed to have been retired by the year 2035 based on ADP's consideration. These plants were switched off in the power flow case and their total generation dispatch was backed down and redispatched against the generation from upstate New York. The Barrett power plant was considered under two scenarios: first, as a plant due for retirement, and second, as a plant due for repowering. If retired, all the thermal units at Barrett, including the gas turbines are considered retired. If repowered, the two steam units are repowered to 250 MW capacity each.

2.5. Analytical Method

Steady-state power flow solution and contingency analysis were used to determine the thermal impact of the OSW injection on the underlying AC system. The analysis was performed using PowerGEM's Transmission Adequacy and Reliability Assessment (TARA) software. The security-constrained redispatch (SCD) function of TARA was utilized in performing the analysis in addition to normal AC contingency analysis. This TARA function determines the optimal generation dispatches and PAR MW schedules to bring the number of thermal overloads to a minimum. This approach complies with the NYISO application of the Minimum Interconnection Standard (MIS) for energy service interconnections. In applying the SCD, generating plants in the New York City and Long Island areas were allowed to participate in the redispatch to resolve thermal violations. For the SCD, no reliability must-run generators were designated.

TARA was also used to determine the impact on transfer capacities on highways and byways for the deliverability testing. This analysis is based on the Deliverability Interconnection Standard (DIS).

Production simulations were conducted using the ABB-Hitachi Gridview software.

2.6. Initial OSW Projects

As of the time of this study, the following OSW projects were considered firm:

- Equinor OSW (NYISO queue Q737) interconnecting at Gowanus for an injection of 800 MW,
- Ørsted OSW interconnecting at Holbrook for 880 MW and
- Deepwater (NYISO queue Q695) Wind Farm at East Hampton 69 kV for 136 MW

2.7. Offshore Wind Interconnection Locations

ADP identified several potential points of interconnection (POI) for OSW in the New York City and Long Island areas. The locations are shown in Figure 2-1.

Figure 2-1: Location of potential OSW POIs.

2.8. Criteria

The applicable aspects of the following standards and criteria were considered in this analysis:

- North American Electric Reliability Corporation ("NERC"), specifically, Standard TPL-001-4 — Transmission System Planning Performance Requirements
- Northeast Power Coordinating Council ("NPCC"), Reliability Reference Directory #1 "Design and Operation of Interconnected Power Systems"

- New York State Reliability Council (“NYSRC”), “Reliability Rules & Compliance Manual for Planning and Operating the New York State Power System,” Version 39, November 10, 2016

Since the study is focused on the thermal loading of facilities, the applicable steady-state criteria are as given in Table 2-1.

Table 2-1: Steady-State Criteria applied in the study

System Condition	Maximum Allowable Facility Loading
Pre-contingency (n-0)	Normal rating
Post-contingency (n-1)	Long Term Emergency Rating (LTE) Except if the facility is a Con Edison underground cable, in which case, the limit is the Short Term Emergency Rating (STE)

The power flow solution options applied for each contingency are summarized in Table 2-2.

Table 2-2: Power Flow Solution Options for TARA[5]/Steady-State Analysis

Case	Transformer Tap-Changers	PARs	DC Taps	Switched Shunts	Area Interchange Control
Pre-Contingency	Stepping	Regulating	Regulating	Regulating	Disabled
Post-Contingency Pre-Adjustment	Fixed	Fixed at pre-contingency angle	Regulating	Continuous controlling devices regulating, discrete shunts locked at pre-contingency settings	Disabled

2.9. Exclusions

All the analyses address thermal n-0 and n-1 constraints issues only. Reliability issues relating to voltage, stability, short circuit, and other technical aspects are not included in the Scope of this study.

5 TARA (Transmission Adequacy & Reliability Assessment) is a power flow program developed by PowerGem LLC.

Section 3. Solo Injection Analysis

This section presents the analysis and findings for solo injection of OSW at selected POIs. OSWs are evaluated for maximum injection capacity with only the following other OSW plants in service:

- 800 MW Equinor Gowanus (NYISO queue Q737
- 880 MW Ørsted Holbrook
- 136 MW Q695 Deepwater Wind Farm

The injection tests assume there are no bus or substations limitations at the individual substations to receive the incoming power from OSW.

However, ADP has noted that potential access limitations have been identified as follows:

- Space limitations at the Farragut, Jamaica and East 13th St substations
- Right of way limitations for new circuits between East Garden City and Valley Stream
- Bus capacity limitation for 1200 MW interconnection at the Ruland Rd 138 kV substation. (NYISO proposes the addition of 345 kV bus at Ruland Rd with a connection to Newbridge substation.)

For each POI, Pterra studied the summer peak injection capacity with no transmission upgrades[6].

3.1. Test for No System Upgrade Facilities

The first set of tests considered the OSW POIs shown in Figure 2-1 for ERIS interconnection without requiring System Upgrade Facilities (SUFs). For this analysis, the Minimum Interconnection Standard (MIS) is assumed to be applicable such that while the POI being studied is retained at its target injection level, all other generation are allowed to redispatch to alleviate thermal overloads.

The imports from New England (via the Cross-Sound Cable) and PJM (via the Neptune HVDC, the NYC PARS and the Linden VFT) are maintained at their base case values, as well as transfers from Upstate NY to Long Island via the Y49/50 submarine cables. The wheeling contract to NYC via Lake Success/Valley Stream is no longer observed since the addition of OSW in NYC and Long Island may replace the import need.

3.1.1. Eastern Long Island

OSW POIs in Eastern Long Island are located east of the Holbrook interface (see Figure 3-1) which has a limited capacity for transfers in the westward direction. The lines of the interface generally constrain the amount of MW that can be delivered to the rest of Long Island. There are a number of other generators in this zone, including Shoreham, Wading River, Port Jefferson (to be retired), Holtsville, Brentwood, Greenport, Nissquog, South Hampton, West Babylon, East End, Flynn and Caithness. Imports from New England over the Cross Sound Cable (CSC) HVDC tie are received at the Shoreham substation. The Deepwater Wind Farm is also located in this zone.

6 With respect to the original power flow models.

The solo injection capacities in this zone range from 250-650 MW, with the highest value identified at Brookhaven.

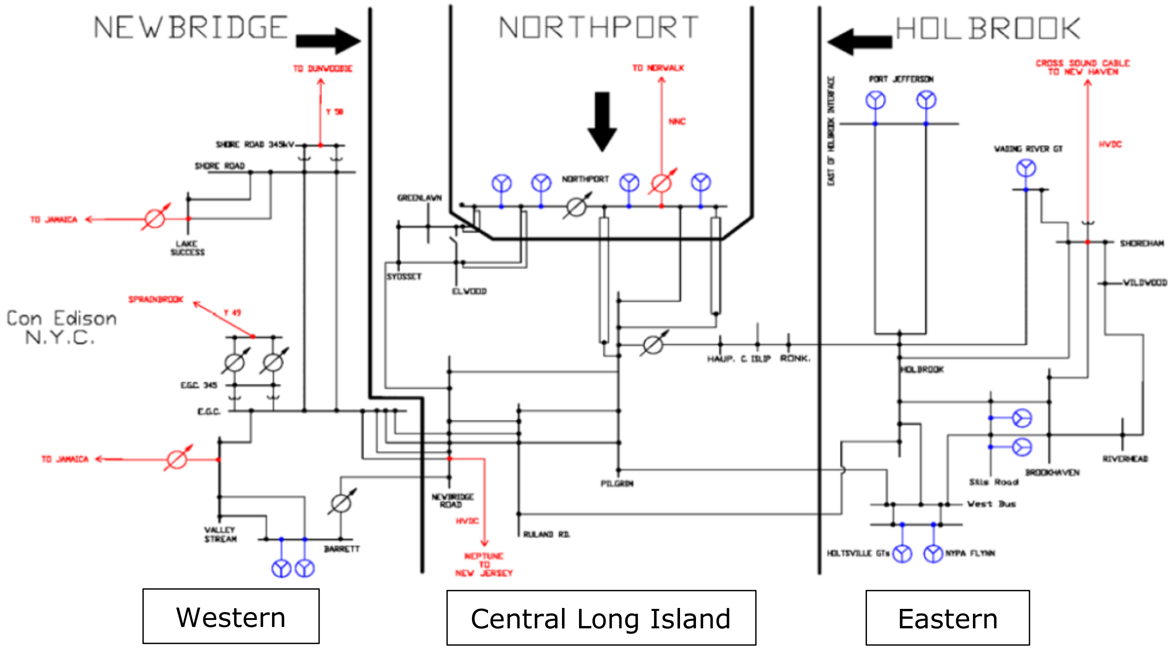

Figure 3-1: Subregions of Long Island Electric System

3.1.2. Central Long Island

Central Long Island is the main load pocket for Zone K. There are few generators in this load pocket, with Pine Lawn as one of the few resources. In the future, this zone will host the Ørsted OSW interconnecting at Holbrook for 880 MW. The capability to deliver power to this load sub-zone in the existing system is constrained by three interfaces: Newbridge, Holbrook and Northport. OSW interconnecting within the Central Long Island sub-zone have the advantage of avoiding the pre-existing constrained interfaces and delivering directly to a load pocket.

OSW POIs at 138 kV in this zone bypass the constrained interfaces and therefore show injection capacities in the range of 1,350-1,800 MW. The highest injection capacity among the POIs evaluated is at Holbrook.

For the two 69 kV POIs tested in this sub-zone, Brightwaters and Brentwood, both showed zero injection capacity. This is due to local constraints on the 69 kV system.

3.1.3. Western Long Island

This sub-zone is west of the Newbridge interface which is constrained by transfers going into Central Long Island. The generation in this zone includes Barrett, Far Rockaway, Freeport, Glenwood, Calpine, Grumman and Trigen.

Initial studies have determined that retirement of the Barrett plant will lead to a transmission constraint that will require a 3rd circuit between Valley Stream and East Garden

City. To avoid the upgrade, at least 300 MW needs to be retained at Barrett for summer peak conditions.

Injection at Valley Stream is limited to 400 MW. At Barrett, there is no injection capacity if Barrett is not retired. If Barrett is retired, the OSW injection capacity is 400 MW. If Barrett is repowered, this capacity is reduced to 50 MW.

3.1.4. Manhattan

The OSW POIs on Manhattan island deliver directly to a large load pocket. For no SUFs, the resulting injection capacities are 1,850 and 1,450 MW, respectively for West 49th St and East 13th St.

3.1.5. Brooklyn and Queens

Likewise, the OSW POIs in Brooklyn and Queens have a large load pocket to deliver to. This results in injection capacities of 1,800-2,500 for 345 kV POI, and 450-1,400 MW for 138 kV POIs. The largest injection capacity is at Gowanus.

3.1.6. Staten Island

The Staten Island OSW POI injection results show capacities in the range of 500-1,550 MW, with the larger capacity associated with the higher voltage.

3.2. Combination POIs

The solo POI injection capacities are not necessarily additive; i.e., if POI A has a capacity of 100 MW and POI B has 150 MW, developing both POIs A and B does not necessarily mean there is a total of 250 MW injection capacity. If POIs A and B are near each other such that they may share use of certain elements of the transmission grid then their combined capacity will tend to be less than the sum of their individual capacities as they jointly load up their shared transmission facilities.

A test was performed to determine the amount of interaction among the study POIs. A preliminary assumption to this test is that POIs belonging to the same sub-zone will tend to have the strongest interaction with each other. The findings of this test are as follows:

- Any two POIs in Zones J and K interconnecting at their maximum solo injection capacity results in a reduction of their combined injection capacity by 8 to 12%.
- However, when the POIs are in close proximity such as Ruland Rd/Holbrook and Gowanus/Fresh Kills, there is a larger reduction in combined capacity due to the common use of nearby transmission elements.

3.3. Considering larger sized OSW interconnections

Two options were considered (1) Increasing the POIs with solo injection capacity below 600 MW to 1200 MW via transmission upgrades and (2) Increasing the POIs with solo injection capacity over 1150 MW to 2000 MW via transmission upgrades.

For the first option, three POIs were considered for this analysis: Hudson, Fox Hill and Valley Stream. All these POIS have solo injection capacities below 600 MW. In order to increase their injection capacity to 1200 MW, each of the POIs will require a number of SUFs.

For the second option, POIs with solo injection capacity of at least 1,150 MW were tested for an injection of 2,000 MW. Of the POIs considered, Gowanus had a solo injection capacity greater than 2,000 MW even without SUFs.

Section 4. Individual OSW Sequence of Development

This section provides results from two representative development sequences A) a planned approach to maximize overall utilization of POIs and cable access routes and B) the current approach of developing each project individually and sequentially.

4.1. Development Sequences

Several development sequences were formulated for study. Each development sequence was tested for System Upgrade Facilities (SUFs) to enable Energy Resource Interconnection Service (ERIS) and System Deliverability Upgrades (SDUs) to enable Capacity Resource Interconnection Service (CRIS). The analyses herein are based on models available at the time of this study and as modified by Pterra.

The actual models to be used by NYISO to conduct subsequent interconnection studies for the OSW plants may vary significantly and produce different results.

Results presented in this report are based on the thermal capacity of the existing and planned NYCA. Further analysis will be needed to address other reliability and operations aspects of the grid including stability, fault withstand, other forms of contingencies (including n-1-1) and extreme events, torsional interactions, power quality, reserve requirements, among others.

4.1.1. Energy Resource Interconnection Service (ERIS) and Associated System Upgrade Facilities (SUFs)

The NYISO conducts a System Reliability Impact Study (SRIS) for each Generating Facility that desires to obtain ERIS. The objective of the study is to determine compliance with the NYISO Open Access Transmission Tariff's Minimum Interconnection Standard (MIS). Where the MIS is not met, the Generating Facility may provide SUFs to enable compliance.

The typical SRIS includes short circuit/fault duty, steady state (thermal and voltage), stability analyses, and other specific analysis. For this present study a limited set of steady-state thermal analysis is conducted. The analyses performed are:

- Steady-state performance using power flow models under Normal conditions (N-0): all lines in-service, and
- Under Single element contingency (N-1): single element outages covering loss of line, cable, transformer, generator, tower, breaker failure, bus section and HVDC lines.

Another form of thermal steady-state analysis known as n-1-1 is not included here.

For each OSW project that is to be interconnected to the New York State Transmission System (NYSTS), an analysis is conducted under summer peak, winter peak and light load scenarios. The base case power flow models used in this study were requested from the New York Independent System Operator (NYISO) as part of the FERC 715 filing and were modified to represent conditions at the time the OSW project is placed into service. The initial summer power flow model for this study is the year 2027 summer peak case. The winter peak case available for this study is the year 2022/23. For the light load study, the light load case available is the year 2022.

In the analyses, the OSW under study is kept at full output and while all other generators, including other OSWs, are re-dispatched using the Security Constrained Dispatch ("SCD") function of the TARA software. For the SCD, no reliability must-run generators were designated. The contingency, monitored and subsystem files used for this analysis are the same as used for the Solo Injection Analysis (see Section 3).

4.1.2. Capacity Resource Interconnection Service (CRIS) and Associated System Deliverability Upgrades (SDUs)

The NYISO conducts a Deliverability Study for Generating Facilities that wish to avail of Capacity Resource Interconnection Service (CRIS). The objective of the study is to ensure that the Facility's output is deliverable under the Deliverability Interconnection Standard (DIS) throughout the Capacity Region where it is to be interconnected and that it does not degrade any interfaces of the NYSTS. Where deliverability at the capacity of the Facility is not possible, System Deliverability Upgrades (SDUs) may be specified.

The analysis is conducted on the summer peak power flow model. Transfer limit calculations are performed using linear transfer simulation in the TARA software. Generation-to-generation shifts are simulated from combinations of zones within the Capacity Region from generation "upstream" of an interface to generation "downstream" of that interface. Simulation of power transfer within each Capacity Region determines the ability of the network to deliver capacity from generation in one (or more) surplus zone(s) to another deficient zone(s) within that Capacity Region.

Contingencies tested in the transfer limit assessment include all emergency transfer criteria contingencies defined by the applicable Northeast Power Coordinating Council (NPCC) Criteria and New York State Reliability Council (NYSRC) Reliability Rules.

Modeling Assumptions

Loads are modeled per the applicable summer peak ATBA case. Load Forecast Uncertainty (LFU) is applied to the Capacity Regions as follows: NYC 5.60% and LI 7.30%.

Generators are modeled based on CRIS (MW) capability of existing generating units, as listed in the 2019 Gold Book. Derates for the generators were applied based on the following factors:

- All rotating generators in NYC -9.98%
- All rotating generators in LI -9.82%
- Solar -50.44%
- Landfill gas -26.72%
- Offshore wind Pmax at 38%

The following imports into Long Island and New York City are modeled:

- Cross-Sound Cable to Long Island 330 MW
- Neptune HVDC to Long Island 660 MW
- Linden VFT 315 MW
- Hudson transmission 660 MW

Net import into NYC is 3800 MW, and into Long Island is 858 MW.

4.1.3. Upgrade Cost Estimates

The costs for implementing the SUFs and SDUs were initially estimated using P50 pro forma prices.

> *Addendum from ADP:*
>
> *Further analysis was then conducted by PSC Consulting to determine installed costs. PSC Consulting analyzed system upgrades using system one-line diagrams, aerial photographs, and other available information to determine major equipment quantities needed to construct the upgrades. Direct construction costs were calculated from the major equipment quantities and unit costs. Escalation factors for project management, mobilization, de-mobilization, engineering, permitting, commissioning, administrative, general overhead, and contingencies were applied to determine total upgrade costs. The total upgrade costs are provided with an accuracy range to account for unpredictability in scope definition, raw material cost variations, and other discrepancies within the estimate.*
>
> *The installation and material unit cost of the major equipment along with the appropriate escalation factors were derived from a variety of sources including publicly available project costs, industry standard costing guides, utility experience, and industry practice. Additionally, unit costs have been adjusted to reflect the local labor market and assumed site conditions.*
>
> *Cost estimates do not include property acquisition, 3rd party payments such as community benefit or other compensation, unforeseen site conditions such as poor soil conditions or environmental remediation, taxes, AFUDC, or other unrelated costs.*

4.2. Planned and Unplanned Development Sequences

Of the various OSW development sequences studied, a sequence based on a planned approach to OSW development resulted in the lowest total cost of SUFs and SDUs. The sequence and associated upgrades are shown in Table 4-1**Error! Reference source not found.**.

An unplanned OSW development sequence results in total upgrade costs of $1.39 billion to $2.61 billion. Such a sequence is shown in Table 4-2.

Table 4-1: Planned OSW Development Sequence

Sequence	POI	Sub-Zone	MW	Loca-tion	System Upgrade Facilities	System Deliverability Upgrades	Total Cost of Upgrades ($M)		
							Low	High	Midpoint
1, 2 and 3	Ørsted Holbrook	Central Long Island	880	LI	None	None			-
	Deepwater	Eastern Long Island	136	LI	None	None			-
	Equinor Gowanus	Brooklyn	800	NYC	None	None			-
4	Rainey	Brooklyn	1200	NYC	None	Two additional 345/138 kV transformers at Rainey; two additional 138 kV lines Rainey-Vernon[7]	$81.4	$152.6	$117.0
5	Ruland Rd	Central Long Island	1200	LI	345 kV interconnection with link to Newbridge	None	$54.5	$102.3	$78.4
6	Gowanus	Brooklyn	2000	NYC	None	None[8]			
7	East Garden City	Central Long Island	1100	LI	Valley Stream-East Garden City 138 kV	None	$67.7	$126.9	$97.3
8	Fresh Kills	Staten Island	1700	NYC	Additional circuits: Fresh Kills-Goethals 345; Goethals-Gowanus 345 kV	None	$155.3	$291.2	$223.3
Totals			9016				*$358.9*	*$673.0*	*$516.0*

[7] These SDUs needed to unbottle Rainey OSW generation.
[8] Deliverability testing procedure did not show an upgrade need although subsequent production simulation identifies an optional upgrade of a new Gowanus-Rainey 345 kV line will increase the delivered capacity factor of the Gowanus OSW.

Table 4-2: Unplanned OSW Development Sequence

Sequence	POI	Sub-Zone	MW	Loca-tion	System Upgrade Facilities	System Deliverability Upgrades	Total Cost of Upgrades ($M)		
							Low	High	Midpoint
1, 2 and 3	Ørsted Holbrook	Central Long Island	880	LI	None	None			-
	Deepwater	Eastern Long Island	136	LI	None	None			-
	Equinor Gowanus	Brooklyn	800	NYC	None	None			-
4	Fresh Kills	Staten Island	800	NYC	None	Gowanus-Goethals 345	$128.6	$241.1	$184.9
5	Gowanus	Brooklyn	800	NYC	None	Gowanus-Rainey 345 kV[9]; two additional 345/138 kV transformers at Rainey; two additional 138 kV lines Rainey-Vernon	$324.7	$608.9	$466.8
6	Holbrook	Central Long Island	800	LI	None	None			
7	Ruland Rd	Central Long Island	1200	LI	345 kV interconnection with link to Newbridge	None	$54.5	$102.3	$78.4
8	East Garden City	Central Long Island	1200	LI	None	None			
9	Brook-haven	Eastern Long Island	1200	LI	Brookhaven-Sills Rd 138 (3); Haupague-Pilgrim 138 (1)	None	$345.8	$648.3	$497.1
10	Barrett	Western Long Island	1184	LI	Barrett-Valley Stream 138 (5); Valley Stream-EGC 138 (3)	None	$540.2	$1,012.8	$776.5
Totals			9000				*$1,393.8*	*$2,613.4*	*$2,003.6*

[9] This SDU is not identified as an SDU in the Planned Sequence but is noted as an optional upgrade to increase delivered capacity factors for the Planned Sequence.

4.3. Production Simulation

Production simulation was conducted to determine the performance of the energy supply system as OSW is introduced into the NYISO grid. The simulations were conducted using the GridView software, which analyzes sequential 8760-hour of system operations.

4.3.1. Model Assumptions

Assumptions pertaining to the development of the production cost database are as follows:

- **Data Sources:** The production cost database represents the NYISO power system with detailed models of generators, loads, and the transmission network within the entire NYISO footprint and adjacent regions including PJM, ISONE, Hydro Quebec and Ontario Hydro. The starting point for development was the ABB 2019 simulation ready database. This database was benchmarked with NYISO's CARIS 2019 updated with the power flow cases from Pterra. (All costs in the production simulation are expressed in 2018 US dollars.)
- **Load Level:** Baseline load forecasts for years 2026 and 2035 from the NYISO 2019 Gold Book were used. The forecasts represent the expected NYCA load and reflect the impacts of energy saving programs and behind-the-meter generation.

  Loads were represented using chronological 8760-hour load curves for each area for the NYISO area. For non-NYISO areas, load shapes were derived from historical load curves as published in FERC Form 715.
- **Transmission:** Pterra developed specific power flow models for the summer and winter peak conditions of 2026 and 2035 Sequence 3. For the purposes of production cost simulation, all interfaces were modeled[10] with their limits. Thermal limits of all transmission lines rated 230 kV and above were enforced; for zone J and K thermal ratings of all lines rated 138 kV and above were enforced. Design contingencies for NYISO were applied.
- **Interface limits for Zone I-K** were updated based on Figure 4-1. The dynamic limit between Coned and LIPA was excluded on the assumption that this limit will not be active once the OSWs come into service.

10 Interfaces were defined based on the definitions adopted by the NYISO.

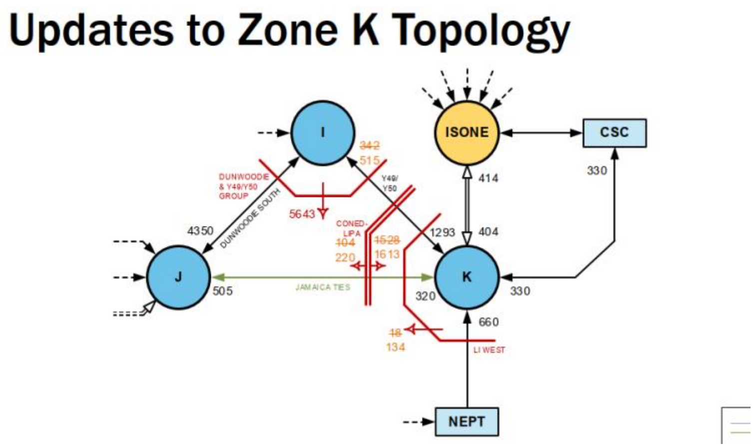

Figure 4-1: Interface Limits Update

- **Thermal Generation:** Thermal units are represented in GridView in detail, including: unit type, fuel type, heat rate blocks, summer and winter capacities, variable O&M, start-up fuel usage, minimum up and down, forced outage, maintenance schedule, emission rate, ramping rate, quick-start, and spinning reserve capabilities. Generation units status and capacity were updated as in the latest NYISO 2019 Gold book.
- **Hydro Generation:** In the GridView model, hydro generators are characterized by Minimum Capacity, Maximum Capacity, Monthly Energy allocation and Variable O&M, all of which can vary monthly and annually. The minimum capacity is treated as run of river generation. The difference between minimum and maximum capacities are treated as dispatchable capacity. This capacity is dispatched for peak shaving, with the constraint that the total cumulative generation in a month will not exceed the monthly energy allocation. The hydro units' monthly energy was obtained from the NYISO website.
- **Solar/Wind Generation:** Wind and solar units within New York were modeled as hourly resources with hourly generation curves. Hourly resources were represented at zero cost and become must-take energy, with a provision for curtailment as necessary. The distributed zonal hourly generation curves for wind and solar units were obtained from the NYISO 2016 CARIS publication.

  For Production Tax Credit (PTC) schedule, the wind curtailment price is applied at -25$/MWh.
- Generation Summary. Generation unit status and capacity were based on the NYISO "2019 LOAD & CAPACITY DATA" (Gold Book), published in April 2019. Typical forced outage rates and durations were used to create generator outage schedules.

4.3.2. Simulations and Analyses

The OSW capacity factors for years 2026 and 2035 are shown in Table 4-3. In 2026, OSW can operate at or near their rated capacity factor of 51.4%. In 2035, there are reductions in the capacity factors for the OSW interconnected at Gowanus and Fresh Kills. These are due to transmission constraints on the outlet of the injected power from the OSW. The constraints are not identified under the Minimum Interconnection and Minimum Deliverability Standards because they occur at off-peak hours of the winter and spring seasons. Figure 4-2 shows the monthly curtailment for year 2035.

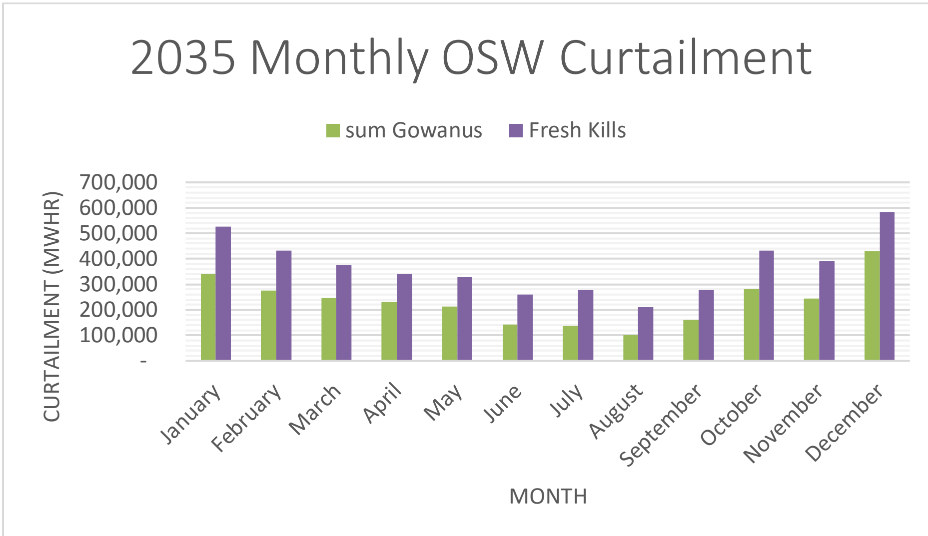

Figure 4-2: Monthly Curtailment of Gowanus and Fresh Kills OSW for the Planned Scenario in 2035

The main cause of curtailments of the Gowanus OSW is the capacity of the transmission lines from Gowanus to Farragut. This is illustrated in Figure 4-3.

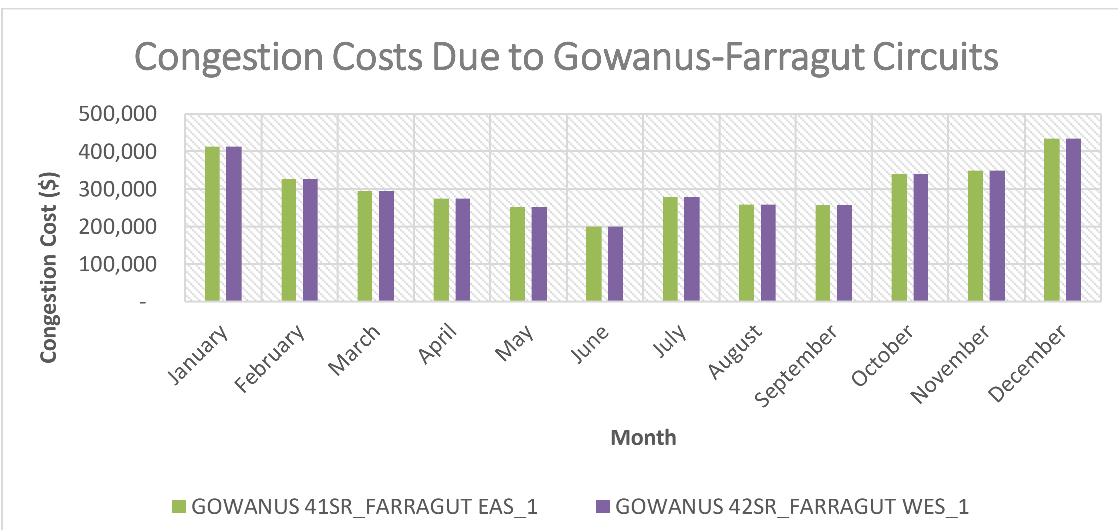

Figure 4-3: OSW Curtailments due to Constraints on the Gowanus-Farragut Circuits in the Planned Scenario in 2035

To increase the capacity factor for the Gowanus OSW, a transmission upgrade, classified as an Optional Upgrade, was considered. A new 345 kV line from Gowanus to Rainey results in an increase of the Gowanus OSW capacity factor to 47.3%.

Table 4-3: Capacity Factors for OSW for Planned OSW Sequence

Sequence	POI	Year 2026	Year 2035	Year 2035 with Optional Upgrades
1, 2 and 3	Ørsted Holbrook	51.4%	51.2%	51.2%
	Deepwater	51.4%	50.3%	50.3%
	Equinor Gowanus	51.4%	40.0%	47.3%
4	Rainey	51.4%	51.4%	51.4%
5	Ruland Rd	51.3%	51.2%	51.2%
6	Gowanus	-	40.0%	47.3%
7	East Garden City	-	49.6%	49.6%
8	Fresh Kills	-	21.6%	18.7%

The energy supply mix for the New York City and Long Island Zones in 2035 is depicted in Figure 4-4.

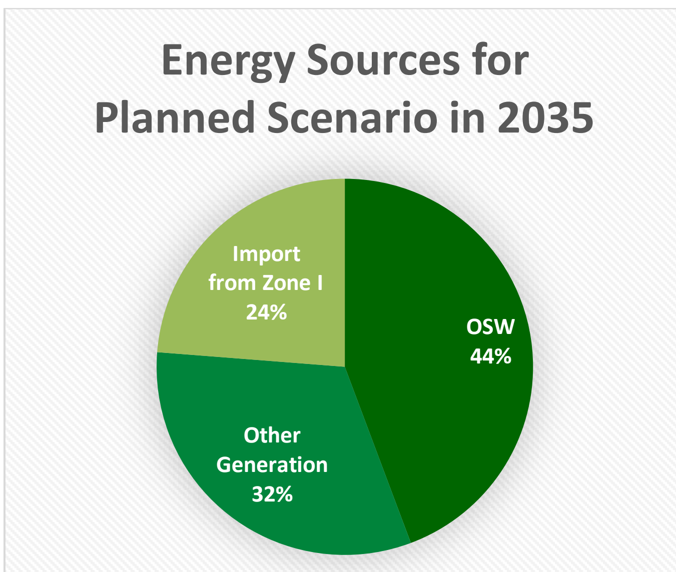

Figure 4-4: Zone J and K Energy Sources With No Optional Upgrades in 2035

For the unplanned sequence, capacity factors range from 47.8% to 51.4% in 2026. The capacity factors are lower in 2035 with 22.4%, 37.4% and 37.6% for the East Garden City, Brookhaven and Deepwater OSW injections, respectively.

Optional upgrades comprising of a new Holbrook-Ruland Rd 138 kV line and a new Dunwoodie-Shore Rd cable can increase the capacity factors for East Garden City and Holbrook OSW but, overall, will require further optional upgrades to bring the overall OSW capacity factor near 50%.

Table 4-4 shows the capacity factors for the unplanned sequence.

Table 4-4: Capacity Factors for OSW for Unplanned OSW Sequence

Sequence	POI	Year 2026	Year 2035	Year 2035 with Optional Upgrades
1, 2 and 3	Ørsted Holbrook	47.8%	39.7%	44.8%
	Deepwater	51.4%	37.6%	37.2%
	Equinor Gowanus	51.4%	51.4%	51.3%
4	Freshkills	47.8%	49.0%	49.1%
5	Gowanus	51.4%	51.4%	51.3%
6	Holbrook	47.8%	39.7%	44.8%
7	Ruland Rd		49.4%	47.1%
8	East Garden City		22.4%	35.2%
9	Brookhaven		37.4%	34.8%
10	Barrett		46.0%	47.4%

Section 5. Conclusions

Solo Injection Analysis

Solo injection capacities were determined for several potential POIs for future OSW. Central Long Island is the main load pocket for Zone K. The highest injection capacity among OSW in this sub-area is at Holbrook. In New York City, the OSW POIs on Manhattan island have solo injection capacities of 1,850 and 1,450 MW. Likewise, the OSW POIs in Brooklyn and Queens have a large load pocket to deliver to resulting in solo injection capacities of 1,800-2,500 MW. The largest solo injection capacity is at Gowanus.

Considering larger sized OSW interconnections

Increasing the capacity of POIs with low solo injection capacity (below 600 MW) to be able to accommodate OSW injections of 1200 MW require expensive system upgrades ranging from $204 million to $448 million.

Gowanus had a solo injection capacity greater than 2,000 MW even without system upgrades.

OSW development sequences

Using the results of the solo injection analysis, interactions between injections, and evaluation of larger injections as a guide and applying knowledge gained from each stage of the study resulted in a number of proposed development sequences. Of the various OSW development sequences studied, a sequence based on a planned approach to OSW development resulted in the lowest total cost of SUFs and SDUs.

In contrast, an unplanned OSW development sequence may result in total upgrade costs approximately four times as high as costs of a planned development.