Renewable Rikers Feasibility Study Report

The New York City Mayor's Office of Climate & Environmental Justice

The City of New York
Mayor Eric Adams

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NYC
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About the Study

The New York City Mayor's Office of Climate & Environmental Justice[1] commissioned the National Renewable Energy Laboratory to prepare a feasibility analysis of siting several renewable energy technologies on Rikers Island to fulfill its obligations under Local Law 17 of 2021. This report summarizes the key findings to inform decisions about future redevelopment of Rikers Island by presenting five different potential renewable energy and battery storage redevelopment scenarios, considering cost savings, resilience, and greenhouse gas emissions reductions, in the context of the city's environmental justice and energy performance mandates and goals, and recommends further planning to advance the development of wastewater and energy infrastructure on Rikers Island to further inform the City's forthcoming decision on how to repurpose Rikers Island.

Special thanks to all of our agency partners for their contributions to this report.

[1] LL17 assigns this obligation to the New York City Mayor's Office of Long-Term Planning and Sustainability, which is now known as MOCEJ.

Executive Summary

Rikers Island is a 413-acre island in the East River in the Bronx where most of New York City's jail facilities are located. With limited transportation connectivity, it is relatively isolated from most New York communities—which narrows the range of potential future uses but also creates a once-in-a-generation opportunity to build critical climate infrastructure to serve New Yorkers.

New York City has adopted aggressive carbon emission reduction and clean energy mandates and legislation, including the 2019 Climate Mobilization Act, which requires citywide emissions reductions from large buildings and municipal operations on an incremental scale until 2050. The city has also committed to achieving carbon neutrality citywide by 2050.[i]

Almost 90% of the electricity that powers New York City's grid is currently generated by fossil fuels, while the opposite is true in upstate New York, where approximately 90% of electricity powering the grid is from zero-emissions and renewable sources. This discrepancy is largely due to the difficulty of siting large-scale renewable generation in dense, urban areas, and building long-distance transmission lines through numerous topographies and jurisdictions to bring renewables from less-dense places into New York City's grid, which the New York Independent System Operator (NYISO) designates as "Zone J."[ii] Rikers Island presents an opportunity to site renewable energy infrastructure within Zone J and support New York City's transition to clean energy.

Local Law 16 of 2021 established the Rikers Island Advisory Committee (Advisory Committee), while Local Law 17 of 2021 directed the Mayor's Office of Long-Term Planning and Sustainability (now the Mayor's Office of Climate & Environmental Justice, or MOCEJ) to study the feasibility of building renewable energy infrastructure on Rikers Island. This report fulfills the requirements of Local Law 17 by examining five scenarios with different combinations of clean energy technologies, and informs the Advisory Committee and public that:

1. While all scenarios help the city realize its renewable energy and carbon reduction mandates, Scenario 5 allows the city to maximize renewable energy infrastructure on Rikers Island and site a modern Wastewater Resource Recovery Facility (WRRF).

2. There is a limited amount of energy that can flow through Rikers Island and connect to New York City's electric grid without adding transmission infrastructure. This includes connecting Rikers Island to New York City's existing power grid, as Rikers Island is currently powered by a cogeneration plant and is not connected to the grid.

Three primary characteristics of Rikers Island and available clean energy technologies determined the array of technologies assessed in the report: (1) surface stability and subterranean characteristics; (2) height restrictions due to the proximity to LaGuardia Airport; and (3) the technologies' commercial maturity. The study initially examined ground source heat pumps, tidal energy, green hydrogen, hydrogen fuel cells, onshore wind turbines (sited on Rikers Island), and offshore wind turbines (sited near Rikers Island), all of which were deemed infeasible for this location. Rikers Island's characteristics are compatible with solar photovoltaic generation, battery storage systems, and offshore wind (OSW) interconnection infrastructure. Separately, the New York City Department of Environmental Protection (DEP) has assessed the feasibility of constructing a WRRF on Rikers Island.[2] Two factors dictated the capacity of each scenario's energy technologies:

1. The physical footprint of Rikers Island is a major constraint. At 413 acres, the current footprint of developable land is restricted by elevation due to the risk of future tidal flooding, coastal storm surge flooding, and anticipated sea level rise caused by climate change. Because of this, the study only considers 343 acres eligible for development.

2. The capacity of the city's existing grid infrastructure is the largest constraint to siting energy infrastructure on Rikers Island. Because this report only considers existing energy transmission infrastructure and infrastructure planned for development as of January 2023, it identifies two existing transmission substations with available hosting capacity: Astoria in Queens and Mott Haven in the Bronx. The hosting capacity of these transmission substations could allow for the interconnection of up to 3,500 MW of additional generation.

OSW converter stations, considered in Scenarios 2-5, are built in increments of 2,000 MW. In these scenarios, battery storage can be scaled to eliminate the need for significant OSW curtailment[3] despite the limited hosting capacity of the Astoria and Mott Haven transmission substations. In Scenario 1, battery storage is scaled based on anticipated need of and assumptions about the New York City energy grid in 2035. In all scenarios, solar is scaled to occupy the remaining developable land.

Based on these assumptions, this report assesses the four clean energy infrastructure and WRRF technologies arranged in five different scenarios. The potential clean energy and economic benefits associated with each scenario are shown in Table ES1 below. The configuration and scale of energy infrastructure development on Rikers Island is flexible and can be adapted to reflect other proposed land uses, technological advances, market conditions, and supply chain considerations.

[2] For DEP's assessment of WRRFs on Rikers Island, please see: https://reimaginerikersdep.cityofnewyork.us/.

[3] Curtailment refers to instances where an electrical generation system deliberately reduces its power output, often when there is insufficient electricity demand to absorb its generation.

Table ES1. Summary of Clean Energy Technology by Scenario							
Scenario	Technology combination	MW Capacity	Total MW	Upfront Construction Costs**	Annual O&M Costs**	Upfront Construction Economic Output	Annual O&M Economic Output
1	Solar	110 MW	541 MW	$600 Million	$45 Million	$151.7 Million	$48.5 Million
	Battery Storage	431 MW / 1,724 MWh					
2	Solar	104 MW	4,224 MW	$1 Billion	$117 Million	$143.1 Million	$14.7 Million
	Battery Storage	120 MW / 480 MWh					
	OSW*	4,000 MW					
3	Solar	92 MW	6,932 MW	$2 Billion	$170 Million	$226.2 Million	$51.5 Million
	Battery Storage	840 MW / 3,360 MWh					
	OSW*	6,000 MW					
4	Solar	70 MW	13, 670 MW	$2 Billion	$430 Million	$294.9 Million	$43.9 Million
	Battery Storage	1,600 MW / 6,400 MWh					
	OSW*	12,000 MW					
5	Solar	9 MW	6, 850 MW	$2 Billion + WWRF***	$168 Million + WWRF***	$176.1 Million	$52.3 Million
	Battery Storage	849 MW / 3,413 MWh					
	OSW*	6,000 MW					
	WRRF	n/a					

Notes: *"OSW" = Offshore Wind Converter Station.

** All dollar values are in approximate 2023 U.S. dollars. Rikers Island is currently powered by a 15 MW fossil fuel co-generation plant and is not connected to the electric grid. Therefore, any plans to redevelop Rikers Island must consider the need to build new transmission cables to connect Rikers Island to the electric grid. However, this report does not incorporate these needs into its analysis.

*** In Scenario 5, all solar, and 9 MW/53 MWh of the assessed battery storage are behind-the-meter, supporting the WRRF, with additional storage front-of-meter designed to limit curtailment of OSW. Scenario 5 economic costs do not include those costs associated with the construction or maintenance of the WRRF. However, DEP estimates the capital cost of a new WRRF is ~$34 billion.

Scenarios 1, 2, 3, and 5 are feasible. The scale of Scenario 4 is not feasible because existing and planned transmission infrastructure is insufficient to absorb the volume of electricity that could travel through or be generated on Rikers Island. New unplanned transmission infrastructure would need to be constructed through decisions that are outside of the city's control.

The city supports Scenario 5, which offers the potential to export clean energy at scales large enough to make significant contributions to its climate and energy transition goals while also transforming how it manages wastewater as a resource. The city acknowledges further planning and analysis to advance design, construction, and operation of climate infrastructure on Rikers Island is necessary to inform the decision regarding how to repurpose Rikers Island, and that planning should be conducted in partnership in collaboration with the Advisory Committee, elected officials, and other stakeholders.

1. Introduction

Rikers Island is an approximately 413-acre island situated in the East River between the Bronx and Queens[iii] that currently includes eight correctional facilities, the majority of New York City Department of Correction's (DOC) facilities.[iv] Rikers Island was sold to New York City in 1884 for use as a municipal waste disposal site for coal ash, food scraps, wood, and other organic materials.[v] It served as one of the city's main municipal landfills until the mid-1930s, growing to several times its original size as waste was landfilled.[vi] The city constructed a new jail on Rikers Island to replace the deteriorating 100-year-old jail and asylum complex on Roosevelt Island (formerly Blackwell's Island) and began using Rikers Island as a jail complex in 1932.[vii] In the 1950s, the city built additional incarceration facilities to expand Rikers Island.[viii]

In October 2019, New York City Council (City Council) passed legislation to close the jail facilities on Rikers Island by 2027.[ix] In February 2021, the City Council passed three additional laws to address the future of Rikers Island after the city closes the jails.[x] Local Law 16 of 2021 established a process for transferring the land and all infrastructure on Rikers Island from the NYC DOC to the NYC Department of Citywide Administrative Services (DCAS) by August 31, 2027.[xi] The law also established the Rikers Island Advisory Committee to evaluate and provide recommendations to the mayor and City Council on potential uses of Rikers Island for sustainability and resiliency purposes.[xii] Local Law 17 of 2021 directed the Mayor's Office of Long-Term Planning and Sustainability (now the Mayor's Office of Climate & Environmental Justice, or MOCEJ) to complete this study to evaluate the feasibility of building renewable energy infrastructure on Rikers Island.[xiii] Finally, Local Law 31 of 2021 directed the New York City Department of Environmental Protection (DEP) to evaluate the feasibility of consolidating multiple Wastewater Resource Recovery Facilities by placing new wastewater infrastructure on Rikers Island.[xiv]

In accordance with Local Law 17 of 2021, this report considers the following:

1. **Economic Costs**: Includes initial costs of construction and annual operation and management (O&M) costs for each renewable energy asset. The number of jobs, associated earnings, economic benefit or gross output, and Gross Domestic Production (GDP)[xv] are provided for both cost types.

2. **Climate Impact**: Examines climate impact under the damages-based value of carbon method.[xvi] This approach is used to inform the climate impacts of clean energy infrastructure deployment on Rikers Island in tons of CO_2 equivalent avoided annually (tCO_2 eq), and dollars per ton of CO_2 avoided. Deployment of clean energy technologies would replace and reduce greenhouse gas (GHG) emissions from fossil fuel generated power.

3. **Rate of Return (ROR)**: Net gain or loss of an investment over a specified time period. This report sets forth various governance, ownership, and energy purchasing structures the city may pursue after the land and infrastructure on Rikers Island is transferred to DCAS. The ROR is dependent on the governance and ownership model chosen.

This study lays out five scenarios to redevelop Rikers Island as a renewable energy hub and to inform stakeholders and city decision-makers as they consider the future development of Rikers Island. The scenarios consider four potential energy systems:

1. **Solar photovoltaics (Solar PV)**: Solar PV is a method of converting energy from the sun into electricity. Flat panels with solar PV cells capture the sun's radiation and convert it to electric power. Rikers Island lends itself to solar PV infrastructure because it has large unobstructed areas of open space.

2. **Battery storage system**: A battery storage system is an electrochemical device that stores energy generated by a power source (e.g., wind turbines, solar panels, or a power plant) to provide on-demand electricity or grid support.[xvii] At scale, battery storage can reduce the need for fossil fuel-powered generation. Battery storage on Rikers Island could support renewable energy production and OSW interconnection.[4]

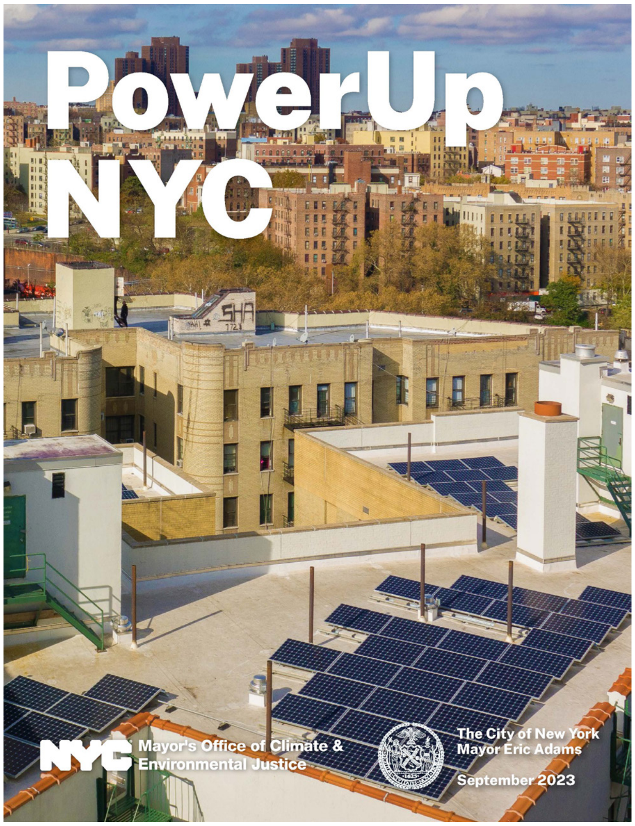
3. **Interconnection of offshore wind (OSW)**: Electricity generated from OSW turbines in the New York Bight, the area offshore of New York State and New Jersey, and other OSW lease areas must be connected to the onshore transmission system.[xviii] Rikers Island has the potential to serve as a site for an onshore convertor station.[xix] Underwater cables would transmit OSW energy to an onshore convertor station that would convert it from direct current (DC) to alternating current (AC), which is the type of electricity used in the electric grid. From there, the clean electricity would flow to the New York City grid.

4. **Wastewater Resource Recovery Facility (WRRF)**:[5] WRRFs receive wastewater from homes, schools, businesses, and factories; remove pollutants; and release cleaned water into nearby waterways.[xx] WRRFs are critical to the protection of public health and the environment but use large amounts of electricity. Additionally, in areas where stormwater combines with wastewater to be processed at a WRRF, the volume of flow may exceed the facility's capacity during heavy rainstorms. When this occurs, a mix of stormwater and untreated sewage discharges directly into the city's waterways. These events are called combined sewer overflows (CSOs). A new, state-of-the-art WRRF on Rikers Island would treat the flows of four existing WWRFs located along the Upper East River. Additionally, a new WRRF could add to New York City's wastewater treatment capacity, improve water quality, reduce CSO discharges, increase energy efficiency, digest and recover biogas, treat biosolids to a higher quality for beneficial use, and increase resiliency from extreme weather events.[xxi]

This report evaluates infrastructure that would position Rikers Island as a renewable energy hub but recognizes that other unanalyzed factors, such as future changes in energy infrastructure and future economic conditions, will inform the decision of how to redevelop Rikers Island. Additional master planning will be needed to develop an actionable implementation plan for Renewable Rikers. This report seeks to build upon publicly available reports previously published by MOCEJ, primarily PowerUp NYC, and therefore does not contain an expansive discussion of the electric grid's general configuration and its associated infrastructure.

[4] Local Law 17 of 2021 specifically requires this report to assess the potential value of developing a battery storage system on Rikers Island.

[5] The use of Rikers Island for wastewater infrastructure was contemplated by stakeholders when the City Council mandated the closure of Rikers Island when, in March 2021, the Council passed Local Law 31, which directs DEP to evaluate the feasibility of consolidating four existing WRRFs onto Rikers Island. For more information, please visit the following link: https://legistar.council.nyc.gov/LegislationDetail.aspx?ID=3983007&GUID=D7B397CD-49EA-4ECE-9C32-1493AB8F0C21.



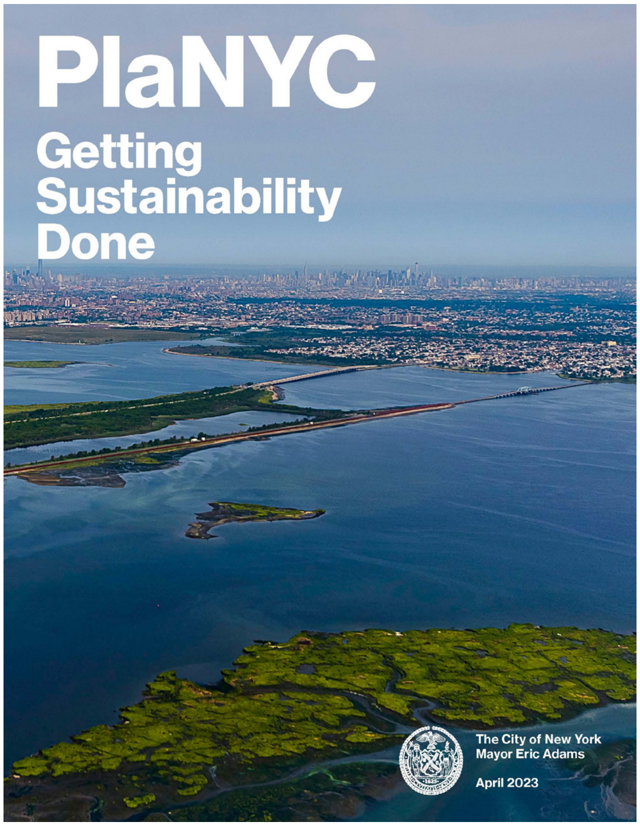


Figure 1. *PowerUp NYC* is New York City's first long-term energy plan. It provides information on basic components of the city's energy systems, outlines opportunities to achieve a just clean energy transition, and the initiatives the city will take to get there.

PlaNYC: Getting Sustainability Done is New York City's most recent climate action plan. It details initiatives the city is taking to protect New Yorkers from climate threats, improve quality of life, and build the green economy.

The scenarios are modular and flexible if the city decides other uses are also feasible on Rikers Island, including urban agriculture facilities, composting infrastructure, or public access. The use of Rikers Island for renewable energy does not necessarily preclude co-locating energy infrastructure with other uses.

2. Overview of Rikers Island's Potential Clean Energy Applications

To mitigate the impacts of climate change and secure a clean, renewable energy future, both New York City and New York State have established aggressive carbon reduction and clean energy goals. New York City—through the 2019 Climate Mobilization Act, other laws,[6] and mayoral commitments—has established citywide emissions reduction mandates for large buildings,[xxii] and for city government operations (including buildings, vehicle fleets, and other city government assets) on an incremental scale until 2050.[xxiii] The city also committed to achieving carbon neutrality citywide by 2050.

Meanwhile, New York State established the Climate Leadership and Community Protection Act (CLCPA),[7] which calls for 70% of the electricity used in the state in 2030 to come from renewable resources and for the electric system to be zero emission by 2040.[xxiv] New York State and City's specific emissions reduction and clean electricity targets are outlined in Table 1.

Table 1. New York State & City Carbon Reduction and Clean Energy Targets

Jurisdiction	Boundary	Mandate	Deadline
New York State	Statewide	40% emissions reduction	2030
	Statewide	70% renewable electricity	2030
	Statewide	100% zero-emission electric system	2040
	Statewide	85% emissions reduction + carbon neutrality	2050
New York City	Government operations	40% emissions reduction[xxv]	2025
	Government operations	100% renewable electricity	2025
	Government operations	50% emissions reductions[xxvi]	2030
	Citywide (buildings > 25,000 ft2)	40% emissions reduction[xxvii]	2030
	Citywide (buildings > 25,000 ft2)	Net zero emissions[xxviii]	2050
	Citywide	Net zero emissions	2050

Notes: "Government Operations" includes GHG emissions attributable to city government operations, including infrastructure, facilities, and other assets owned or leased by the City for which the City pays all or part of the annual energy bills.[xxix] "Citywide" means GHG emissions that occur within the New York City jurisdictional boundary including from city government and the private sector.[xxx]

[6] New York City's mandates require emissions reductions from a fiscal year 2006 baseline for city government operations, and from a calendar year 2005 baseline for citywide reductions.
[7] New York State's CLCPA was signed into law in July 2019. It requires New York to reduce economy wide GHGs from 1990 levels. For more information on the CLCPA, please see: https://climate.ny.gov.

To meet these ambitious carbon reduction and clean energy mandates, New York State and New York City set targets to deploy renewable energy sources including solar, battery storage, and OSW, outlined in Table 2.

Table 2. New York State & City Solar, Battery Storage, and OSW Commitments[xxxi]

Jurisdiction	Technology	Boundary	Goal	Deadline
New York State	Distributed Solar	Statewide	6,000 MW	2025[xxxii]
	Battery Storage	Statewide	6,000 MW	2030[xxxiii]
	Offshore Wind	Statewide	9,000 MW	2035[xxxiv]
New York City	Solar	Citywide	1,000 MW	2030[xxxv]
	Solar	Government property	100 MW	2025[xxxvi]
	Battery Storage	Citywide	500 MW	2025[xxxvii]

As of February 2024, the city has installed 24 MW of solar PV on property it owns, meeting almost 25% of the 2025 goal, and approximately 494 MW of solar PV has been installed citywide, meeting almost 50% of the 2030 goal.[xxxix] As of December 2023, 23 MW of battery storage has been installed across New York City, contributing to its storage goal of 500 MW by 2025.[xl] New York City Economic Development Corporation (EDC) is facilitating the interconnection of OSW energy to New York City's grid as New York State continues to develop OSW in the New York Bight, working towards the state's goal of 9,000 MW by 2035.

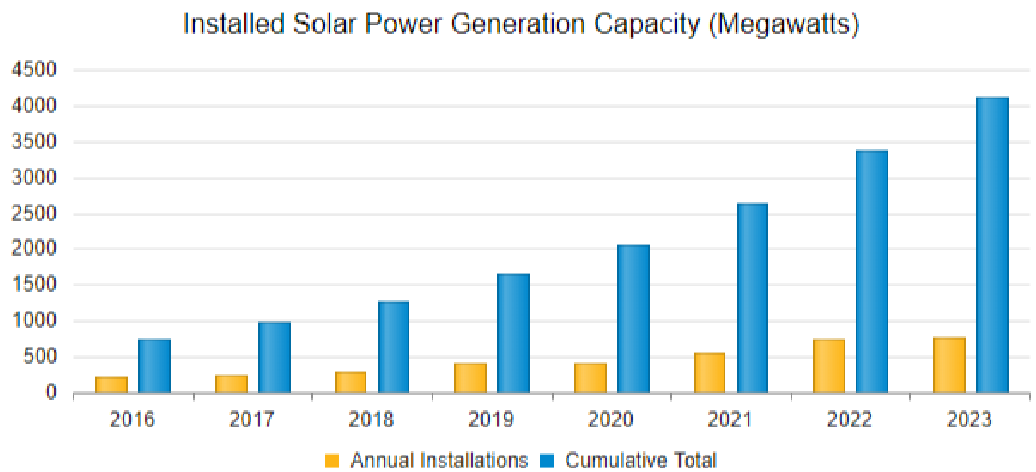


Figure 2. Annual and cumulative solar installed in New York City.[xxxviii]

Disclaimer, Solar Statistics for New York City: Data in the charts below reflects only those solar installations that received funding through NYSERDA from 2000-present. The total number and capacity of solar projects in the jurisdiction selected may be higher.

2.1 Choosing the Renewable Energy Systems

Rikers Island presents a significant opportunity to transform New York City's energy infrastructure with clean energy generation, transmission, and storage capacity. Local Law 17 directs the city to examine the feasibility of siting renewable energy sources combined with battery storage facilities on Rikers Island. In addition to solar, battery storage, and OSW interconnection, this study examined several other clean energy technologies: land-based wind turbines, OSW turbines (sited near Rikers Island), ground-source heat pumps (GSHP), green hydrogen and fuel cells, and tidal energy.

This study uses three primary considerations to guide the evaluation of renewable energy technologies to determine whether they are appropriate to site on Rikers Island:

1. **Landfill stability and subterranean characteristics**: Landfill stability and subterranean characteristics prohibit the safe construction of GSHP and land-based wind turbines. While almost a century has passed since the last refuse barge was emptied on Rikers Island, the legacy of landfilling waste on Rikers Island has resulted in toxic gas leakages and frequent sewage back-ups.[xli] The instability of the landfill and shifts in the soil have caused chronic structural issues in the eight operational jails, including cracked walls and broken pipes.[xlii] These stability issues prohibit land-based wind turbines, because their foundations require deeper and more stable substrate than the majority of Rikers Island provides.[xliii]

2. **Building height restrictions**: Rikers Island is close to LaGuardia Airport (LGA) and falls within the LGA flight obstruction area set forth in Article 6 Chapter 1 of the New York City Zoning Resolution.[8] Development on Rikers Island is therefore limited to 50-foot-tall structures on the eastern or southern shores and 150-foot-tall structures on its western shore.[xliv] Due to these restrictions, land-based wind and OSW turbines (adjacent to Rikers Island) are not possible.

3. **Commercial maturity**: Technologies in the "pilot" stage were not considered commercially viable.[9] Tidal energy and green hydrogen are emerging technologies that have yet to be deployed at commercial utility-scale and are therefore not likely to be commercially viable by 2030. However, if these technologies advance from the pilot stage, they should be reevaluated.

2.2 Solar

Rikers Island's large footprint of available land is unshaded by surrounding buildings, which makes the site ideal for a commercial scale solar project. Four of the five scenarios presented in this report would add 70 MW or more total solar capacity to New York City, an increase of at least 20-33% of the city's current capacity. Solar arrays can be easily integrated onto rooftops of other facilities and above parking lots sited on Rikers Island, are not hindered by height restrictions, and can be built on a landfill.

Solar presents significant economic opportunity to create local jobs.[xlv] Solar is a mature, flexible, and cost-competitive renewable energy technology that can be used for local generation of clean electricity with minimal operations and maintenance (O&M) costs.

[8] ZR 61-30 (defining airport references imagery surfaces to include the "the approach surfaces, the transitional surfaces and those parts of the horizontal surface and the conical surface which coincide with such approach surfaces and transitional surfaces.").
[9] A pilot program is a small-scale, exploratory venture intended to test the viability of a project or policy.

2.3 Battery Storage

Battery storage on Rikers Island could store energy generated by solar arrays and, in four of the five scenarios, OSW power generated along the Atlantic Coast and transmitted to Rikers Island via underwater high voltage transmission lines. The opportunity to develop a roughly 340-acre parcel of land within New York City is unusual. Rikers Island presents a unique way to build a system integrating all three technologies at scale.

When installed at a facility behind-the-meter,[10] a battery storage system can serve individual electricity consumers and provide several benefits such as:

1. **Energy arbitrage**: Because electricity is priced higher during peak demand, battery storage systems can be strategically charged at off-peak times, then discharged during peak periods to avoid or reduce consumption from the grid, called energy arbitrage. This saves consumers money and takes pressure off the grid, improving local reliability.
2. **Optimizing renewable generation**: Renewable energy, such as wind and solar, does not generate electricity continuously. Battery storage can store energy generated by solar arrays or wind turbines during periods of sunny or windy weather and discharge electricity at night or when the wind is not blowing to maintain a consistent energy supply.
3. **Resiliency and backup power**: Battery storage can also serve as a short-term alternative to fossil fuel generators. As a backup power source for critical facilities, battery storage can provide resilient clean energy for emergency response, health care, and key communications facilities during an outage.

Utility-scale front-of-meter[11] battery storage systems can provide additional reliability, resiliency, and transmission benefits to the electric system, such as:

1. **Avoiding renewable energy curtailment**: At times, solar or wind systems may generate excess electricity that cannot be used on the grid—there is more supply than demand. Rather than curtail production, battery storage allows solar or wind generation systems owners to store this energy for a later time.
2. **Relieving transmission congestion**: Utility scale batteries, when located close to New York City consumers, can reduce grid congestion, which can reduce costs to utilities and result in lower electricity rates.
3. **Reducing dependence on fossil fuel plants**: When battery storage is deployed at utility-scale in tandem with solar or wind generation, it can reduce reliance on fossil fuel-based power plants that only operate during high demand periods, referred to as “peaker” plants. Peaker plants, which serve to help avoid blackouts, are generally older, less efficient, higher emitters than other power plants, and tend to be located in disadvantaged communities.

[10] Solar and storage can be installed “behind-the-meter” where it provides electricity directly to a building or facility. Behind-the-meter solar electricity can also flow to the grid (where the electric utility passes it along to sell to another customer), but in that case it must pass through the facility’s electric utility meter (often giving a credit to the facility’s account).
[11] Alternatively, solar and storage can be constructed “front-of-meter,” meaning it delivers electricity directly to the electric grid, and it is only consumed after passing through a facility’s electric utility meter. Front-of-meter solar arrays often generate several megawatts or more of electricity, where behind-the-meter arrays are much smaller.

4. **Reduced capital construction**: Utility-scale battery storage systems also can allow transmission regulators to avoid more costly transmission expansion projects. Because the costs of capital transmission projects are paid for by increased utility rates, storage may reduce costs to consumers.

Rikers Island is an optimal location for large, utility-scale battery storage installations due to the opportunity to pair them with solar and OSW infrastructure. Rikers Island is zoned as a C8-2 commercial district, which permits the siting of larger battery storage systems and does not allow for future housing uses. Despite its relative isolation and current lack of space available for public use, it is outfitted with infrastructure, such as fire hydrants, that is required by the New York City Fire Department (FDNY) for energy storage systems.[xlvi] Battery storage assets will not violate Rikers Island height restrictions, and unlike land-based wind turbines or GSHP, do not require extensive substrate excavation.

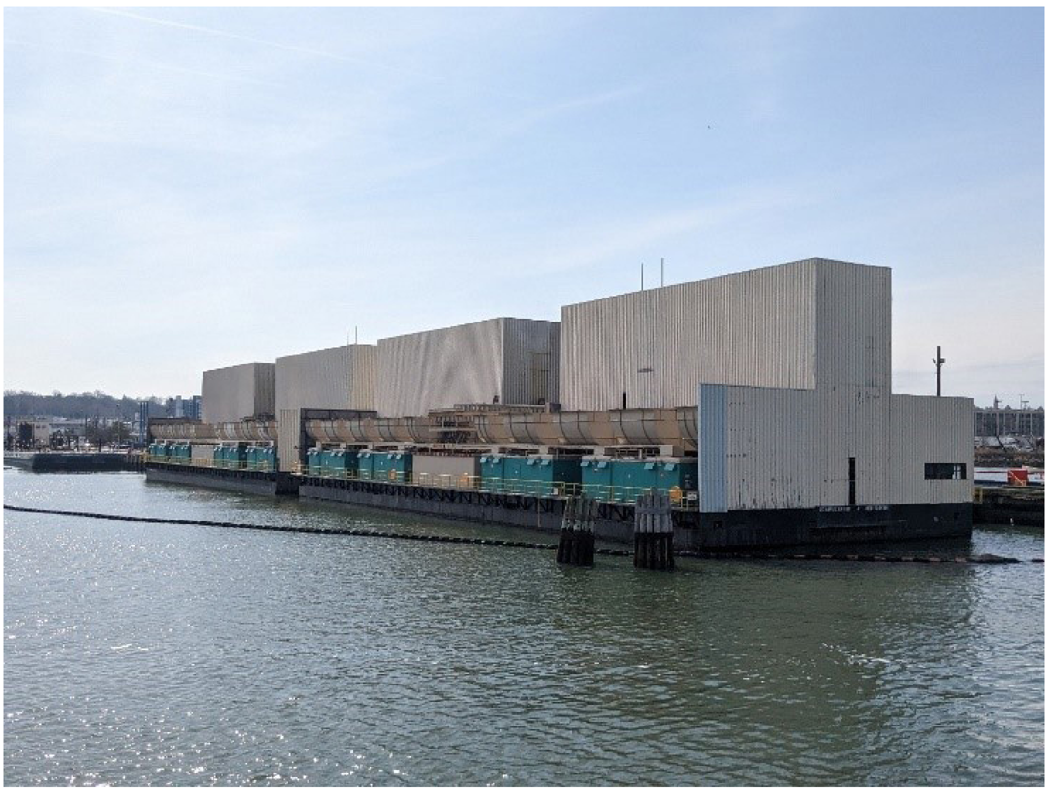


Figure 3. “Peakers in Brooklyn.”[xlvii]

Utility-scale battery storage systems, like those that could be deployed on Rikers Island, are currently limited to a four-hour storage duration because of the limits of technology on the market. However, as battery technology improves, storage duration could become longer and provide greater reliability benefits. For the purposes of this study, however, all five scenarios include battery storage systems with storage durations of four hours. If a 100 MW battery storage system were fully charged, it could expend energy for four full hours at 100 MW. In doing so, it will have discharged 400 MWh (100 MW x 4 hours = 400 MWh).

2.4 Converter Station for Interconnection of Offshore Wind Power

The growing OSW industry plays an important role in New York City's clean energy transition. The commercialization of OSW in the energy market, however, poses unique challenges and considerations unlike those discussed above. OSW generation has significant onshore infrastructure needs. Onshore locations must be equipped with converter stations and a point of interconnection to transmission substations. New York City is a densely built urban environment with limited undeveloped space.

Figure 4. A Modular-Multilevel-Converter station, similar to what could be built on Rikers Island.[xlix]

Wind turbines always generate AC current, but for transmission distances longer than approximately 30 miles, converting AC to DC current minimizes energy losses. Therefore, converter stations are typically built in central locations within wind production areas to convert the current from AC to High Voltage Direct Current (HVDC) and increase its voltage, enabling the electricity to travel long distances to shore. Once the HVDC power reaches shore, it must be converted back to AC at an onshore converter station, with the output interconnected to the grid at a transmission substation. Rikers Island could serve as a site for one or more converter stations.[xlviii]

Voltage Source Converter (VSC)-HVDC stations (see figure 9 in Appendix B) require a footprint of approximately 13.6 acres per 2,000 MW increment and can be collocated adjacent to each other. The VSC-HVDCs serve to convert electricity from DC to AC. Development of new transmission lines would interconnect OSW generation to the grid at one of two existing transmission substations: Astoria or Mott Haven.

Box 1. EDC & "Offshore Wind NYC: Equitable Opportunity for a Sustainable Future"

EDC is a mission-driven not-for-profit organization led by a board appointed by the New York City mayor, borough presidents, and the City Council speaker. EDC projects reflect the priorities of New York City government and strive to situate New York City as the global model for inclusive innovation and economic growth. Fueled by the diversity of New York City's people and businesses, EDC works to strengthen the city's competitive position and facilitate investments that grow quality jobs and cultivate dynamic, resilient, and livable communities throughout the five boroughs. In 2021, EDC issued the "Offshore Wind NYC: Equitable Opportunity for a Sustainable Future" plan to use the city's workforce to manifest an equitable, sustainable future by way of advancing the offshore wind industry in New York City.[l] The plan has three core strategies:

1. *Site Location & Infrastructure*: Develop onshore infrastructure to support construction and operation of 12 GW of offshore wind energy.
2. *Business & Workforce*: Leverage large-scale infrastructure investments for trainings and other long-term workforce and local-business capacity development.
3. *Research & Innovation*: Catalyze new technologies and operational approaches for offshore wind in New York City.

EDC is also in the process of transforming the South Brooklyn Marine Terminal in Sunset Park, Brooklyn into a world-class OSW port that will serve as a construction, maintenance, and operation hub for developers and operators.

As OSW capacity off the coast of New York grows, there will be a need to identify and site viable cable routes and points of onshore interconnection to the grid that are sufficient to meet New York State and New York City's long-term OSW targets.[li] Rikers Island represents an additional landfall location that can be used to support future, growing capacity.

Construction of an OSW converter station would not exceed the height restriction, nor does it present issues with being built on landfill, as converter stations do not require being sunk into the ground like other wind generation equipment. New York City's space constraints for both underwater and on-land infrastructure, the limited capacity of existing transmission substations to accept additional generation, and complex permit processes to build and connect new electrical capacity will continue to be significant challenges.

2.5 Wastewater Resource Recovery Facilities

DEP operates New York City's 14 WRRFs, which receive wastewater from homes, schools, businesses, and factories from the sewer system; remove pollutants; and release clean water into the waterways.[lii] The process takes about eight to ten hours. Wastewater undergoes several treatment processes at these facilities that closely mimic how wetlands, rivers, streams, and lakes naturally purify water. WRRFs also recover energy, nutrients, and other resources from the treatment process.[liii]

DEP has completed a parallel study to assess the feasibility of building a new WRRF on Rikers Island. The new WRRF would consolidate four WRRFs on the Upper East River that are located near Rikers Island: Hunts Point, Tallman Island, Bowery Bay and Wards Island.[liv]

The four WRRFs, built between 1939 and 1952, serve a combined population of over 3 million people, and have a combined dry weather capacity of over 700 million gallons per day. The four WRRFs operate in densely populated neighborhoods in Manhattan, the Bronx, and Queens[lv] and have little-to-no space for expansion to accommodate future population growth, increased wet weather flows, and anticipated regulatory requirements. DEP also has goals to end the discharge of CSOs and expand flooding resilience.[lvi] As these WRRFs approach 100 years of service, significant and costly upgrades will be needed for DEP to continue to maintain wastewater treatment and meet future needs at their current locations.

A new, state-of-the-art WRRF could add wastewater treatment capacity, improve water quality, reduce CSO discharges, increase energy efficiency,[lvii] be designed to better recover biogas, treat biosolids for beneficial use, and be more resilient from extreme weather events.[lviii] A consolidated WRRF on Rikers Island could be co-located with other public services, including renewable energy infrastructure.

3. Qualitative Analysis of Ownership & Business Models

While all five scenarios would significantly reduce carbon emissions in New York City, the governance structure, which defines the ownership and operation responsibility for energy infrastructure, can affect the costs and benefits of each scenario to New York City.

3.1 Sale of Electricity & Environmental Attributes

There are several revenue streams associated with the generation and storage of electricity, all of which are applicable to the solar and storage in each scenario.

- **Sale of Electricity**: Utility-scale generation systems generate electricity that is sold in two ways. First, generators can contract to sell power directly to load-serving entities, which then sell that power to their own customers. Second, generators can sell power within the wholesale power market. In New York, any clean energy generated for market sale is sold in the New York State wholesale power market operated by NYISO.[lix]
- **Environmental Attributes**: A Renewable Energy Certificate (REC)[12] is a mechanism that places a monetary value on the environmental attributes of clean energy generation, namely the avoidance of GHG emissions.[lx] One REC is equivalent to one MWh of energy. RECs provide additional revenues to renewable generators and can incentivize investment in renewable generation systems, which are often more expensive to construct than fossil fuel generation. RECs can be structured in two ways that influence potential revenue streams. A "bundled" REC represents both the renewable attribute and its associated power.[lxi] The purchase of bundled RECs represents the sale of the positive environmental attributes of the generated energy and the delivery of that energy to the purchaser, but is increasingly uncommon and RECs generated on Rikers Island are unlikely to be sold bundled with electricity. An "unbundled" REC separates the environmental attributes of the renewable asset (e.g., avoided GHG emissions, proof of renewable generation) from the generated power.[lxii] This allows for the power to be sold as a commodity within the region in which it is interconnected, while the renewable attributes can be sold anywhere.

3.2 Ownership & Business Models for Battery Storage and Solar

Front-of-meter battery storage and solar infrastructure on Rikers Island could be developed under three primary contracting structures.

3.2.1 City Ownership of Battery Storage and Solar

In the city ownership model, the city would (1) procure the design, construction, and equipment, (2) own the infrastructure, and (3) be responsible for O&M. The city would maintain its position as a primary decision maker for the site and infrastructure. Additionally, as described below, city

[12] Throughout all five scenarios, only solar, not battery storage, can generate RECs for possible sale. This is because batteries store energy (renewable or fossil fueled), but they do not generate any on their own. Therefore, battery storage can never be an original source of a REC. For offshore wind, the production facility (i.e., the wind turbines), not the converter stations, is the source of the RECs.

ownership of such systems can provide a significant source of ongoing revenue. Though long-term return on investment is possible, the upfront capital expenditure required to construct solar and storage infrastructure at the scale contemplated for Rikers Island is very high. Even after the infrastructure is fully installed, there will be additional and continual maintenance requirements and other ongoing costs.

If the city chooses to own the infrastructure, it may be able to partially offset some costs if federal or state funding sources are available at the time of construction. For example, the 2022 federal Inflation Reduction Act (IRA) allows public agencies, as non-tax paying entities, to monetize the federal investment tax credit (ITC) through a new mechanism called "Elective Pay," which is expected to offset up to 30% of the cost associated with any storage or solar system's construction.[lxiii] In addition to ITCs for renewable energy systems' construction, the IRA allows public entities to receive production tax credits (PTC) from renewable energy production.[lxiv] Should similar federal incentives be available when energy is flowing from Rikers Island, the city could receive both tax benefits and revenues from electricity sales.

The city's treatment of RECs will influence its potential revenue streams. If the city chooses to bundle RECs, a buyer will make one payment for the physical delivery of energy and its renewable attributes. If, more likely, it chooses to unbundle RECs, there are three revenue stream configurations:

- Option 1: The city retains the REC for its own benefit, retiring them to claim the benefits of using renewable energy, and sell the energy generated on Rikers Island.
- Option 2: The city retains the energy for its own consumption, for example to operate the WRRF, and sell the RECs.
- Option 3: The city sells both the RECs and the energy.

There are extensive state regulatory and administrative requirements governing the sale of the RECs. The precise structure will require further legal analysis and may involve the New York City Public Utility Service (NYC PUS).[lxv] The administrative structure may affect the city's legal right to claim use of renewable energy generated at Rikers Island. The purchaser of the RECs would claim the renewable attributes and the associated GHG emissions reductions.

3.2.2 Lease or Concession

The city could enter into a lease or concession agreement with a third-party developer.[lxvi] Under these agreements, the developer would construct the solar and energy storage infrastructure sited on Rikers Island. In return, the developer would make payments to the city for the use of the land. This payment is distinct from any profits generated from the solar and stored electricity, which would flow to the developer. Instead, the developer would make a rental payment to the city that would be based on a market appraisal of the property developed as a large-scale clean energy facility. A lease would be competitively bid, as required by state and local law, thereby maximizing the lease payment.

A concession agreement, on the other hand, would license long-term site access and incorporate a fee structure to generate revenue to the city for the use of its property. The fee would be based on a financial analysis and revenue projection of the proposed energy facility conducted by the developer.

If the city pursues a concession or lease it would solicit developers through a competitive solicitation process[lxvii] that sets forth the development requirements. Any lease or concession must also comply with the city's Uniform Land Use Review Procedure (ULURP).[lxviii] ULURP is the standardized procedure set forth in the New York City Charter whereby certain land use actions, including the lease of city land, are publicly reviewed under mandated time frames. ULURP also requires input or approval from key participants like the Department of City Planning (DCP) and City Planning Commission, community boards, borough presidents, borough boards, the City Council, and the mayor.

3.2.3 Power Purchase Agreement

The city could contract with a third-party developer, via a competitively solicited Power Purchase Agreement (PPA), to install, own, and maintain the battery storage and solar infrastructure on Rikers Island.[lxix] The developer would assume all responsibility, financial and otherwise, for design, construction, financing, and O&M for the duration of the agreement with the city. The city would maintain ownership of Rikers Island and commit in the PPA to purchase the electric power generated and stored for the period set forth in the contract, typically around 20 years. A PPA would allow the city to purchase electricity, while eliminating up-front capital construction cost for the city and reduce the city's risk relating to long-term O&M complications. Under a PPA, the developer would take advantage of any available tax credits and receive income from the sale of electricity and RECs.

Box 2. City Owned Solar
The city owns several solar arrays on its property and, at other sites, has installed solar installations via PPAs. The city has also entered into a power sales contract, administered by DCAS, with the New York Power Authority (NYPA), which then entered into PPAs with competitively selected solar developers. In fall 2023, the city announced it would install solar PV systems at over 60 city-owned buildings in Brooklyn and Queens through an agreement with NYPA to add over 30 MW of solar PV generation capacity and up to 10 MW of large-scale battery storage to provide energy to power city operations.[lxx] The 60-plus city-owned buildings will be made up of New York City public school rooftops and six DEP WRRFs, including installations at the Wards Island WRRF, projected to be the largest clean energy installation at a wastewater treatment facility anywhere in the world. In addition to these clean energy installations, other active solar installations will bring the city's total solar capacity to 70 MW once construction is complete. By the end of 2025, DCAS will be provide the annual electricity equivalent of roughly 11,500 New York City homes.

Under a PPA, the city could purchase electricity with a bundled or unbundled REC. Meanwhile, the developer would be responsible for the sale of any remaining power not purchased by the city in the NYISO's wholesale power markets.

3.3 Ownership & Business Models for Offshore Wind Interconnection Infrastructure

New York State leads the nation in the number and scale of projects in its wind development pipeline. In the CLCPA, New York State committed to developing 9 GW of OSW by 2035 (see Figure 5).[13] The state has begun to develop significant OSW generation capacity off the coast to implement this goal, led by NYSERDA, which has issued multiple competitive solicitations for OSW development by qualified companies. NYSERDA has released four solicitations for offshore wind projects.[lxxi]

The New York State Climate Action Council (NYSCAC)[14] is advocating for the deployment of up to an additional 20 GW of OSW to serve New York State by 2050. The city anticipates 9 GW of the OSW will be developed and interconnected to its grid. Achieving this goal will require the construction of several OSW turbine fields along New York and New Jersey's Atlantic coasts and an expansive network of new transmission and interconnection infrastructure off and onshore. Future OSW projects could interconnect to one or more OSW converter stations on Rikers Island.

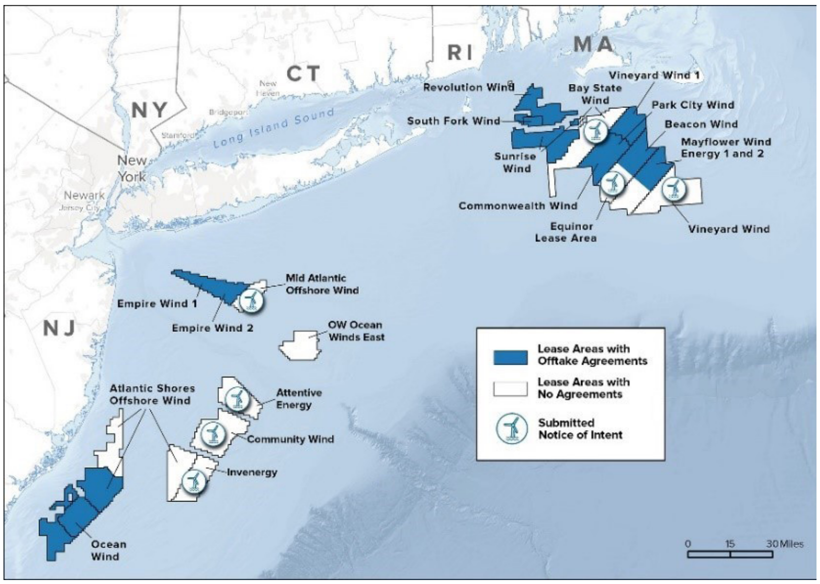


Figure 5. New York State OSW lease areas with and without offtake agreements, and lease areas which have submitted a Notice of Intent (July 29, 2022).[lxxii]

NYSERDA plays a key role in the development of OSW via its purchase of Offshore Wind Renewable Energy Certificates (ORECs) from projects.[lxxiii] Like RECs, ORECs represent the environmental attributes of OSW generation. One OREC is equivalent to one MWh of electricity generated from an OSW asset. ORECs incentivize the development of OSW because these credits create a source of revenue that, in addition to revenues from the sales of energy and capacity in the NYISO's wholesale electricity markets, cover the cost of constructing and operating the projects. NYSERDA issues competitive solicitations for ORECs. Once a project is selected, the developer enters into a contract with NYSERDA for the ORECs associated with the project's production of electricity. Load serving entities in New York are then required to purchase those ORECs from NYSERDA in proportion to the amount of customer load they serve.

[13] OSW projects in the current pipeline do not rely on a future substation being built on Rikers Island.
[14] The NYSCAC is a 22-member body that prepared the roadmap to achieve the state's bold clean energy and climate goals. The NYSCAC advises New York's governor on recommended policies and actions to help meet New York's CLCPA requirements. See: https://climate.ny.gov/resources/climate-action-council.

4. Prospective Clean Energy Technology Integration Configurations & Analyses

All five scenarios include battery storage and solar generation, and four of the five scenarios include OSW interconnection facilities. Scenario 5 also assumes the construction of a WRRF, which would consume electricity generated by solar and stored by battery storage sited on Rikers Island.

Table 3. Summary of Clean Energy Technology Capacity by Scenario

Scenario	Technology Combination	Solar	Battery Storage	OSW Converter Station(s)	Total MW
1	Solar & Battery Storage	110 MW	431 MW / 1,724 MWh	None	541 MW
2	Solar, Battery Storage & OSW Station	104 MW	120 MW / 480 MWh	4,000 MW	4,224 MW
3	Solar, Battery Storage & OSW Station	92 MW	840 MW / 3,360 MWh	6,000 MW	6,932 MW
4	Solar, Battery Storage & OSW Station	70 MW	1,600 MW / 6,400 MWh	12,000 MW	13,670 MW
5	Solar, Battery Storage, OSW Station & WRRF	9 MW	849 MW / 3,413 MWh	6,000 MW	6,850 MW

Notes: In Scenario 5, all solar, and 9 MW/53 MWh of the listed battery storage are behind-the-meter. All other solar and battery storage is front-of-meter.

4.1 Determining Clean Energy Technologies' System Sizes

Two factors dictated the capacity of the technologies in each scenario: (1) the physical footprint of Rikers Island and (2) the capacity of New York City's existing electric grid infrastructure to absorb new renewable power.

The total Rikers Island footprint is 413 acres. Based on GIS analysis, approximately 51 acres of the land will be limited by projected sea level rise, tidal flooding, and coastal storm surge flood risk caused by climate change and low elevation. Therefore, the total available area after accounting for the sea level rise and flood risks would be just over 361 acres.

To account for access roads and other infrastructure, the report assumes a 5 percent buffer area (5 percent of 361.45 acres) slightly greater than 18 acres. This leaves approximately 343 acres available to install clean energy technologies (except for Scenario 5, where two thirds of Riker Island's area would be occupied by the WRRF).

Table 4. Summary of Clean Energy Technology Footprints (in acres) by Scenario

Scenario	Technology Combination	Solar	Battery Storage	OSW Converter Station(s)	Total Acres
1	Solar & Battery Storage	329 acres	14 acres	None	343 acres
2	Solar, Battery Storage & OSW Station	312 acres	4 acres	27 acres	343 acres
3	Solar, Battery Storage & OSW Station	275 acres	28 acres	41 acres	343 acres
4	Solar, Battery Storage & OSW Station	195 acres	53 acres	95 acres	343 acres
5	Solar, Battery Storage, OSW Station & WRRF	30 acres	28 acres	41 acres	99 acres

Notes: Refer to Appendix C for detailed calculations. DEP has stated a WRRF would require a footprint of approximately 245 acres. The remaining Rikers Island acreage is covered by roads and building exclusion zones.

4.1.1 Constraints of Rikers Island Infrastructure Footprint Availability

This study used data from the 2014 United Nations' Intergovernmental Panel on Climate Change (UNIPCC)[lxxiv] to consider future risk from coastal flooding and sea level rise, and data from the Federal Emergency Management Agency (FEMA) relating to current storm surge risk. Meanwhile, future projections are based on the New York City Panel on Climate Change's (NPCC) 2019 projections.[15]

Tidal Flooding

Rikers Island does not currently experience significant tidal flooding, which occurs when water from regular tides breaches typically dry land, even without storms. While climate change is causing greater tidal flooding, the future impacts on Rikers Island are expected to be minimal. DCP mapped future tidal flood zones in accordance with the National Oceanic and Atmospheric Administration's (NOAA) 2010 Digital Elevation Model for New York City.[lxxv] The layers illustrate the scale of potential flooding on land, not the exact location, and do not account for erosion, rapid subsidence,[16] or future construction. As shown in the diagram below, in the 2100s Rikers Island is not at high risk for tidal flooding. However, recurring flooding could present risks to infrastructure constructed along the shoreline.

Figure 6. Map of mean daily high tide at Rikers Island in 2100.[lxxvi]

[15] Future flood projections are based on the NPCC 2019 projections because the updated 2024 NPCC assessment was unavailable at the time of analysis.
[16] Subsidence is a general term for downward vertical movement of the Earth's surface, which can be caused by both natural processes and human activities.

Coastal Storm Surge Flooding

Small portions of Rikers Island's coastline are currently vulnerable to coastal storm surge flooding, which occurs when a storm's wind and wave effects push a surge of sea water onto normally dry upland areas. The extent of flooding can be exacerbated when a storm's wind and rain coincide with high tide, and in particular, "king tides" that occur during full moons.[lxxvii] Portions of Rikers Island are vulnerable to the 1 percent annual chance flood (also referred to as the "base flood" or "100-year flood") and are considered special flood hazard areas (SFHAs), as designated by FEMA.[lxxviii] The SFHA is divided into zones that distinguish different risk levels.[lxxix] The zones relevant to this feasibility study include Zones AE, VE, and X:

- Zone AE: Areas of high risk with wave heights under 1.5 feet. Zone AE includes base flood elevations.[lxxx]
- Zone VE: Areas that have the highest risk, due to wave heights between 1.5 and 3 feet. Zone VE includes base flood elevations.[lxxxi]
- Zone X (shaded): Areas with a 0.2% annual chance flood (or 500-year flood), which pose moderate flood risk.[lxxxii]

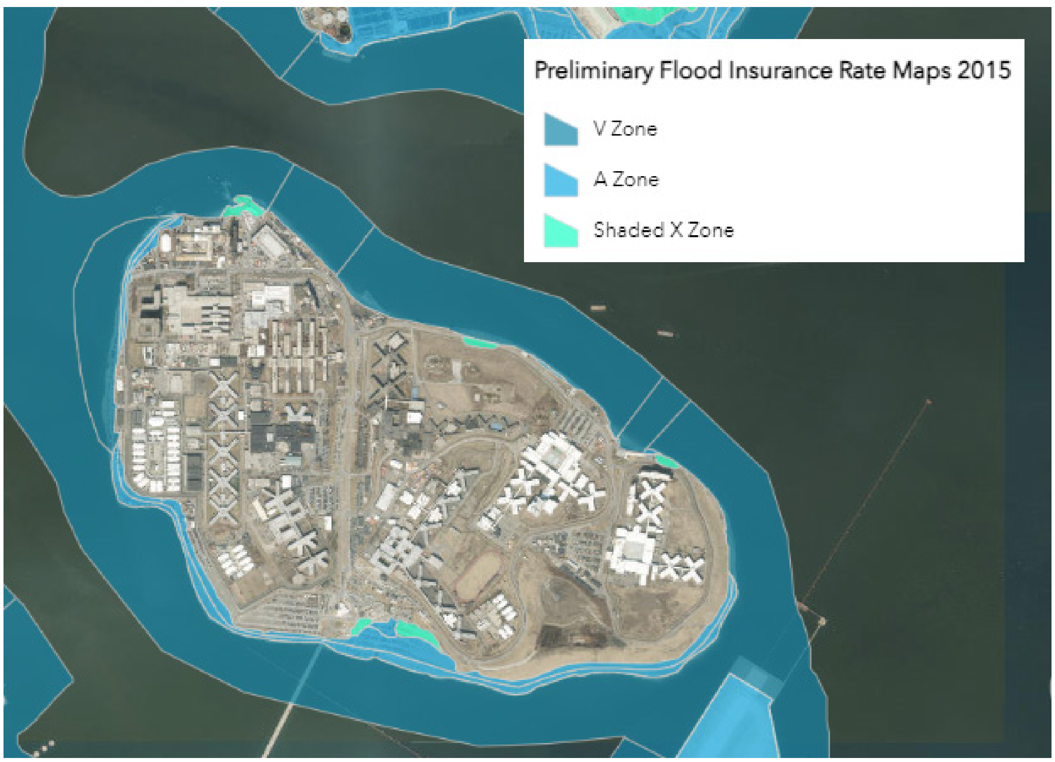


Figure 7. Map of 2015 1% and 0.2% Annual Chance Flood at Rikers Island.[lxxxiii]

In the future, Rikers Island could bear significant risk of more widespread flooding caused by storm surge as more frequent extreme weather and sea level rise induced by climate change will exacerbate coastal storm surge flood risk. Infrastructure at lower elevations, including large inland portions of Rikers Island, could be in danger.

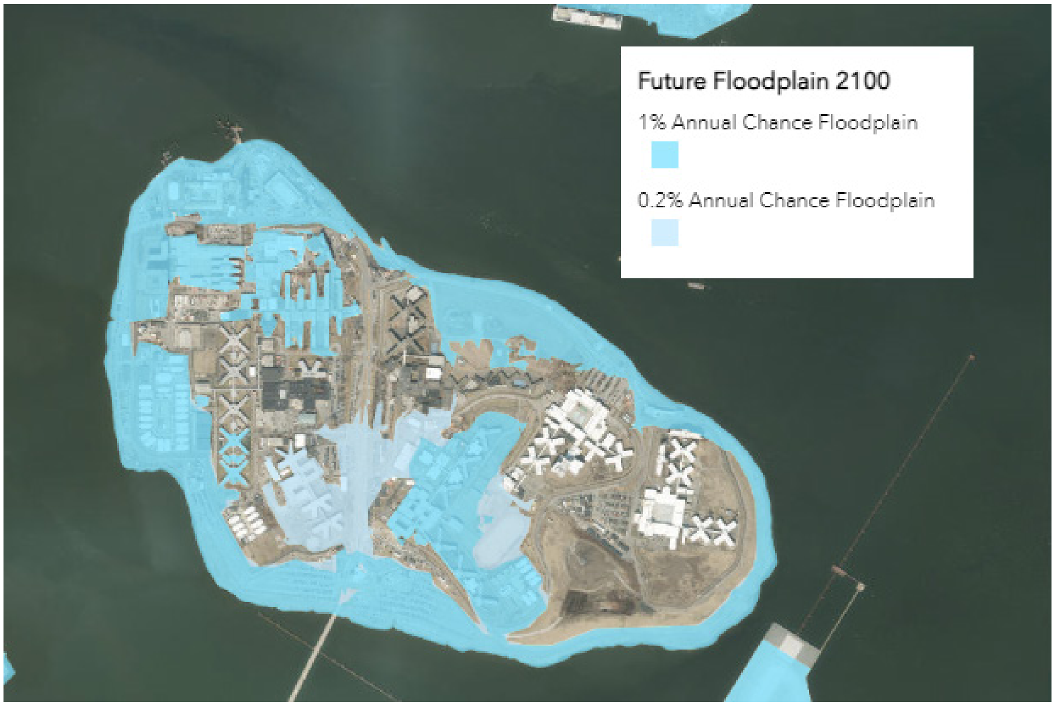


Figure 8. Map of Rikers Island 2100 1% and 0.2% Annual Chance Floodplains.[17]

To reduce these future risks, energy infrastructure developed on Rikers Island must be elevated, or Rikers Island must be elevated with clean fill. This study's scenarios are approximations and assumptions about buildable acreage must be revisited during further planning and design. After 2026, all city capital agencies will be required to comply with the City's Climate Resilient Design Guidelines, which ensure that new and retrofit infrastructure sufficiently addresses risk posed by current and future climate hazards including flooding from extreme precipitation, sea level rise, and storm surge.[lxxxiv]

4.1.2 Constraints of Existing Electric Grid to Absorb Rikers Island Clean Energy Exports

This study limits the scale of solar, battery storage, and OSW power that could flow from Rikers Island to the electric grid based on the assumption that electric facilities constructed on Rikers Island would connect to two existing transmission substations: Astoria in Queens and Mott Haven in the Bronx, shown in figure 10 in Appendix B. The available hosting capacity, or the gap between the maximum level of power that currently flows through a substation, and maximum potential safe level of power that the station could accept, is limited at these two substations.[lxxxv] If OSW generation flowing through a Rikers Island converter station is greater than the Astoria and Mott Haven transmission substations' hosting capacity, that generation must be either:

1. Deliberately curtailed by locking wind turbines stopping generation, which is inefficient and reduces the amount of clean energy generated, or
2. Stored in battery storage and released when wind turbines are no longer operating at their maximum capacity and there is enough customer demand, or at times when there are no grid congestion issues limiting power injection from Rikers Island.

[17] The 2100 future floodplains are based on a layering of high estimates for sea level rise by NPCC on top of the 2015 PFIRM Base Flood Elevations for the 1% annual chance floodplain and on top of the stillwater flood elevations for the 0.2% annual chance floodplain. For more information please see: https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/nyas.12590.

Battery storage can be sized to store the amount of OSW generated power above the available hosting capacity at the interconnection point (Astoria or Mott Haven). This would limit or eliminate the need to curtail solar and OSW generation that could flow from Rikers Island.

This report assumes that only upgrades to New York City's grid and clean power projects planned as of January 2023 have been completed and there are no additional upgrades, which could expand or contract the capacity of the electric grid. Under these assumptions, the hosting capacity of the Astoria and Mott Haven transmission substations limit maximum power intake to approximately 3,500 MW.

Scenario 1 optimizes both battery storage and solar. For Scenarios 2-5, which include OSW, the capacity of the converter station is proposed in increments of 2,000 MW, the fixed size of HVDC converter stations. Battery storage was then scaled to allow the maximum OSW generation while still transmitting a constant 3,500 MW into the electric grid. For each scenario, solar is scaled to optimize the remaining available land.

The existing hosting capacity at the Astoria and Mott Haven transmission substations could be filled by other projects before decisions about Rikers Island space use have been made and implemented. Therefore, any actual decisions on renewables deployment to Rikers Island should be accompanied by a more recent assessment of the Astoria and Mott Haven transmission substations' hosting capacity.

4.2 Development Impacts Analysis

In addition to generating and transmitting renewable energy, repurposing Rikers Island for renewable energy infrastructure would create high-skill jobs and provide economic and climate benefits.

Table 5. Analysis Terms Definitions[lxxxvi]

Term	Definition
Jobs	This report uses the term job in place of the commonly used technical term, full-time equivalent (FTE). One job is the equivalent of one person working a 40-hour week, for 52 weeks. Two people working full-time for six months equals one job. Two people working a 20-hour week for 12 months also equals one job. Jobs are not limited to those who work for an employer; they could include other types of workers, such as self-employed. These jobs include direct, indirect, and induced jobs.
Earnings	Any type of income from work, generally an employee's wage or salary and supplemental costs paid by employers, such as health insurance and retirement.
Economic Benefit or Gross Output	The total amount of economic activity or sum of all expenditures that occur within an economy. If a developer purchases a locally manufactured $500,000 wind turbine rotor blade that includes $100,000 of locally procured fiberglass, the gross output is $600,000.
GDP[lxxxvii]	The total aggregate dollar value of an industry's production to a region and includes labor payments, property-type income (including profits), and taxes.
Tons, Avoided Carbon (tCO_2 eq)	The climate impacts of clean energy infrastructure deployment on Rikers Island in tons of CO_2 equivalent avoided annually (tCO_2 eq), and $/ton of CO_2 avoided.

This study assesses each scenario's economic activity as employment during construction and operation. Economic impacts for each scenario are shown in two tables, one for the duration of system construction and one for the system's useful life.[18] The jobs numbers are associated with the construction, installation, and upkeep of the storage systems, solar arrays, and converter stations plus supply-chain manufacturing jobs that support the construction and ancillary industries.

This study also considers each scenario's climate benefits, expressed as annual tons of CO_2 equivalent avoided through renewable energy infrastructure development. These values were derived using New York City's Local Law 97 2030 emissions factor,[19] as any development on Rikers Island would most likely not come online until after 2030. Battery storage does not have additive avoided carbon emissions because the technology stores and dispatches renewable electricity. Emissions savings are attributed to solar and OSW to avoid double counting.

[18] This study's analyses do not include economic impact assessments for construction of new transmission lines to Rikers Island from offshore wind generation or to transmission substations at Mott Haven or Astoria because the detailed analysis (e.g., line routings, detailed transmission expansion planning, equipment specifications, etc.) were beyond its scope.
[19] Rules for Local Law 97 of 2019 consider the 2030 NYC grid to have an emissions factor of 0.000145 tCO_2e/kWh.

Table 6. Summary of Tons of Avoided Carbon (tCO_2 eq) in Each Scenario					
Scenario	Technology combination	Solar	Battery Storage	OSW Converter Station(s)	Total tCO_2 eq
1	Solar & Battery Storage	139,722	0	None	139,722
2	Solar, Battery Storage & OSW Converter Stations	132,101	0	5,080,800	5,212,901
3	Solar, Battery Storage & OSW Converter Stations	116,858	0	7,612,200	7,729,058
4	Solar, Battery Storage & OSW Converter Stations	88,914	0	15,242,400	15,331,314
5	Solar, Battery Storage, OSW Converter Stations & WRRF	11,432	0	7,621,200	7,632,632

The table below provides an estimate of the initial economic costs associated with each scenario based on presumed activities and specific sets of input costs for both construction and O&M.

Table 7. Initial Economic Costs by Scenario		
Scenario	Upfront Construction Costs	Annual O&M
1	$631,908,748	$44,998,210
2	$1,018,878,178	$116,606,646
3	$2,136,803,836	$170,091,933
4	$2,455,889,558	$340,846,180
5*	$2,118,484,093	$167,983,053

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.
*Scenario 5 economic costs do not include those associated with the construction or maintenance of the WRRF.

The transformation of Rikers Island will require sizeable investments in master planning, environmental review, decommissioning and demolition, and construction of additional infrastructure, none of which are included in the scope of this study. Rikers Island is not currently connected to the New York City power grid, making new transmission cables to connect Rikers Island to existing transmission infrastructure necessary. A comprehensive master plan and financial analysis are needed to accurately assess the financial costs and benefits of redeveloping Rikers Island.

4.3 Scenario 1: Battery Storage & Solar

Scenario 1 includes only battery storage and solar. The battery storage and solar would sit front-of-meter and feed New York City's electric grid.

4.3.1 Analyses of Benefits, Challenges, and Considerations

The battery storage capacity assumed for this study is 431 MW/1724 MWh, which would require a 14.37-acre footprint (at 0.033 acres per MWac). The remaining buildable acres on Rikers Island would be available for solar, sufficient to support a utility-scale ground mounted solar system of 110 MW, which both Astoria and Mott Haven's current hosting capacity can easily accommodate.

Given Rikers Island's annual average daily solar radiation of ~4.71 kWh/m2, the Scenario 1 solar system could generate anywhere between 140-150 GWh of carbon-free electricity each year. This electricity would avoid about 139,722 tons of CO_2 annually and could be sold directly on the NYISO wholesale market. This is equivalent to 31,000 cars off the road. Alternatively, energy generated could be stored in the battery storage system and released for sale daily in the NYISO wholesale market if there is sufficient demand for the power and the bid price is low enough for the battery output to be dispatched.

4.3.2 Jobs and Economic Development Impacts

Scenario 1's construction and installation work would support an estimated 841 jobs, 168 jobs installing battery storage and 673 solar installation jobs. This sum also includes supply-chain manufacturing jobs supporting the construction and ancillary industries. The total estimated economic impact during construction for workers' aggregate earnings is $74.5 million. The analysis also estimates total economic activity across industries and workers, or economic output at $151.7 million; and construction GDP at $105.7 million. As a result, the initial construction impacts for Scenario 1 have an upfront cost of $1,168,038 per MW.

Table 8. Scenario 1 Initial Construction Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (110 MW)	673	$51.9	$101.4	$74.3
Battery Storage (431 MW)	168	$22.6	$50.3	$31.4
Total	**841**	**$74.5**	**$151.7**	**$105.7**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 1's O&M needs would create an estimated 182 long-term jobs annually for the lifetime of each system: 158 supporting battery storage and 24 for solar. O&M includes impacts across all sectors, including on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. These jobs include, but need not be limited to, technicians, managers, administrative professionals, and contractual and manufacturing workers providing replacement and input materials for maintenance. The economic benefits of O&M include $16.2 million in total worker earnings; $48.5 million in total added economic output across all industries and workers; and $30.0 million in GDP. Additionally, Scenario 1 O&M impacts result in a cost of $83,176 per MW annually.

Table 9. Scenario 1 Annual System O&M Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (110 MW)	24	$1.7	$3	$2.3
Battery Storage (431 MW)	158	$14.5	$45.5	$27.7
Total	**182**	**$16.2**	**$48.5**	**$30**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

4.4 Scenario 2: 4,000 MW Offshore Wind Converter Stations with Battery Storage & Solar

In addition to solar and battery storage, Scenario 2 also incorporates a 4,000 MW OSW converter station on Rikers Island. The remaining buildable area on Rikers Island could support a 120 MW/480 MWh battery storage system and 104 MW solar array.

4.4.1 Analyses of Benefits, Challenges, and Considerations

Construction of modular 4,000 MW converter stations would enable large-scale OSW fields in the Atlantic Ocean to interconnect to the New York City power grid via underwater HVDC transmission cables.

The hosting capacity of the Astoria and Mott Haven transmission substations limit maximum power intake to approximately 3,500 MW. Given that (VSC)-HVDC converter stations can only be built in increments of 2,000 MW, Scenario 2 assumes the construction of 4,000 MW of converter stations to maximize available hosting capacity while minimizing the need for curtailment. This assumption derives from the finding that a 120 MW, 4-hour capacity battery storage system paired with the 4,000 MW converter stations likely eliminates the need for curtailment of the additional 500 MW of OSW (except for 6 hours annually).

The converter stations and battery storage system would occupy 27.2 acres and four acres, respectively. This would leave 312 acres for a 104 MW solar array, which could generate between 132-142 GWh of electricity yearly. The added capacity of the converter stations and solar array would produce enough energy annually to avoid about 5,212,901 tons of atmospheric CO_2 emissions, equivalent to 1.2 million cars off the road. Adaptive design practices could allow construction of one or more additional 2,000 MW converter stations on Rikers Island if future OSW and converter station developments enable additional transmission capacity to interconnect to the grid.

4.4.2 Jobs and Economic Development Impacts

Scenario 2's construction would support an estimated 935 jobs, with 38 jobs installing battery storage, 304 jobs supporting construction of the OSW converter station infrastructure, and 593 jobs installing solar. The total economic impact for worker aggregate earnings, the total economic activity across industries and workers, and GDP are estimated to be $78.1 million, $143.1 million, and $106.4 million respectively. The total upfront cost per MW for Scenario 2 is $241,212.

Table 10. Scenario 2 Initial Construction Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (104 MW)	593	$45.8	$89.4	$65.5
Battery Storage (120 MW)	38	$5	$10.7	$7.2
OSW Converter Stations (4,000 MW)	304	$27.3	$43	$33.7
Total	**935**	**$78.1**	**$143.1**	**$106.4**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 2's O&M needs would create an estimated 91 long-term jobs, 31 supporting battery storage, 21 for solar, and 39 supporting the OSW converter stations. This includes impacts across all sectors, including on-site O&M workers, business and supply chain jobs, and employment supported by collateral impacts. The economic benefits of O&M include $5.4 million in worker earnings; $14.7 million in total added economic output across all industries and workers; and $9.1 million in GDP. Annual O&M cost per MW for Scenario 2 is $27,606.

Table 11. Scenario 2 Annual System O&M Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (104 MW)	21	$1.5	$2.6	$2
Battery Storage (120 MW)	31	$2.9	$9	$5.5
OSW Converter Stations (4,000 MW)	39	$1	$3.1	$1.6
Total	**91**	**$5.4**	**$14.7**	**$9.1**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

4.5 Scenario 3: 6,000 MW Offshore Wind Converter Station with Battery Storage & Solar

Scenario 3 assumes construction of 6,000 MW of OSW converter stations on Rikers Island in addition to 840 MW/3,360 MWh 4-hour battery storage and a 92 MW solar array.

4.5.1 Analyses of Benefits, Challenges, and Considerations

Scenario 3 is sized to maximize interconnection capacity of Scenario 2 without requiring significant curtailment given Astoria and Mott Haven substations hosting capacity and available land.

If 6,000 MW of OSW generation flowed through converter stations on Rikers Island, 840 MW / 3360 MWh of 4-hour battery storage is required to reduce curtailment to below 0.1%.[lxxxviii]

The 6,000 MW converter stations would occupy 40.8 acres and the battery storage would require another 28 acres. The remaining land would be sufficient to install 92 MW of solar. A solar array of 92 MW can generate anywhere between 117-126 GWh of carbon-free electricity each year. The total OSW and solar generation would avoid about 7,729,058 tons of atmospheric CO_2 emissions annually, equivalent to 1.7 million cars off the road.

4.5.2 Jobs and Economic Development Impacts

In Scenario 3, construction would support an estimated 1,239 jobs, with 327 jobs installing battery storage, 456 jobs supporting the construction of OSW converter station infrastructure, and 456 jobs installing solar. The total economic impact for worker aggregate earnings, the total economic activity across industries and workers, and GDP are estimated to be $117.6 million, $226.2 million, and $158.4 million respectively. Scenario 3 initial construction would result in a cost of $308,252 per MW.

Table 12. Scenario 3 Initial Construction Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (92 MW)	456	$32.6	$63.7	$46.7
Battery Storage (840 MW)	327	$44	$98.1	$61.2
OSW Converter Stations (6,000 MW)	456	$41	$64.4	$50.5
Total	**1,239**	**$117.6**	**$226.2**	**$158.4**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Long-term jobs created by Scenario 3's O&M needs are estimated at 235, with 154 supporting battery storage, 23 for solar, and 58 from the OSW converter stations. This includes impacts across all sectors, including on-site O&M workers, supporting business and supply chain jobs, and employment supported through ancillary impacts. The economic benefits of O&M include $17.2 million in worker earnings; $51.5 million in total added economic output across all industries and workers; and $31.2 million in GDP. Annual system O&M cost impacts for Scenario 3 are $24,537 per MW.

Table 13. Scenario 3 Annual System O&M Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (92 MW)	23	$1.5	$2.5	$1.9
Battery Storage (840 MW)	154	$14.2	$44.3	$27
OSW Converter Stations (6,000 MW)	58	$1.5	$4.7	$27
Total	**235**	**$17.2**	**$51.5**	**$31.2**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

4.6 Scenario 4: 12,000 MW Offshore Wind Converter Stations with Battery Storage & Solar

Scenario 4 assesses the development of 12,000 MW of OSW converter stations on Rikers Island. The rest of Rikers Island could hold 1,600 MW/6,400 MWh of battery storage and 70 MW of solar. Given existing transmission infrastructure limitations, it is unfeasible to flow this much energy through Rikers Island in the near future. This study chose to examine a scenario with 12,000 MW because 12,000 MW is the largest iteration of 2,000 MW OSW converter stations that could fit their peak load through the larger hosting capacity at Sprainbrook and Dunwoodie transmission substations (north of New York City in Westchester County). The 12,000 MW scenario allows for the study to analyze Rikers Island's maximum clean energy export capacity.

4.6.1 Analyses of Benefits, Challenges, and Considerations

The 12,000 MW of OSW converter station capacity would occupy 81.6 acres (or 20% of the total current surface area of Rikers Island). To best limit curtailment assuming interconnection at Sprainbrook and Dunwoodie, explained below, these converter stations would need to be combined with a 1,600 MW/6,400 MWh four-hour battery storage system, which would require another 53.3 acres. The land that remains would be sufficient to install 70 MW of solar. A solar array of this size can generate anywhere between 89-95 GWh of carbon-free electricity each year. Scenario 4's total generation would avoid 15,331,314 tons of CO_2 annually, the equivalent of 3.4 million cars off the road.

At 12,000 MW, Scenario 4's peak scale of transmission would require more than three times the combined projected available hosting capacity of Astoria and Mott Haven. Absent massive curtailment, this scenario would be operationally unfeasible and require prohibitively expensive upgrades to the surrounding power grid infrastructure, which is outside the city's control. Additionally, upgrades of this scale are not currently planned and unlikely to be in place before Rikers Island is redeveloped.

Generation of this magnitude could be physically absorbed through the Sprainbrook and Dunwoodie transmission substations and delivered to counties north of New York City for consumption. However, as the cost of land is dramatically lower further upstate, renewable generation tends to be much less costly to develop than in New York City or the Atlantic Ocean (i.e., more profitable). Therefore, it is unlikely that renewable electricity transported from Rikers Island would be cost competitive with locally generated wind or solar upstate (even before accounting for the cost of the new transmission lines necessary to transport this power upstate).

4.6.2 Jobs and Economic Development Impacts

In Scenario 4, construction would support an estimated 1,596 jobs, with 385 jobs installing battery storage, 913 jobs supporting construction of OSW converter station infrastructure, and 298 installing solar. The total economic impact for worker aggregate earnings, the total economic activity across industries and workers, and GDP are estimated to be $158.1 million; $294.9 million; and $207.6 million respectively. Upfront costs per MW in Scenario 4 are $179,655.

Table 14. Scenario 4 Initial Construction Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (70 MW)	298	$23	$45	$33
Battery Storage (1,600 MW)	385	$53.1	$121	$73.6
OSW Converter Stations (12,000 MW)	913	$82	$128.9	$101
Total	**1,596**	**$158.1**	**$294.9**	**$207.6**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

243 long-term jobs will be created by Scenario 4's O&M, with 113 supporting battery storage, 14 for solar, and 116 for the OSW converter stations. This includes impacts across all sectors, including on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. The economic benefits of O&M include $14.4 million in worker earnings; $43.9 million in total added economic output across all industries and workers; and $25.9 million in GDP. The annual O&M cost per MW for Scenario 4 is $24,934.

Table 15. Scenario 4 Annual System O&M Impacts				
Technology	Jobs	Earnings	Output	GDP
Solar (70 MW)	14	$1	$1.8	$1.4
Battery Storage (1,600 MW)	113	$10.4	$32.8	$19.8
OSW Converter Stations (12,000 MW)	116	$3	$9.3	$4.7
Total	**243**	**$14.4**	**$43.9**	**$25.9**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

4.7 Scenario 5: 6,000 MW Offshore Wind Converter Stations with Battery Storage, Solar, & a WRRF

Scenario 5 assumes the construction of a new WRRF on Rikers Island. The estimated footprint of the new WRRF is approximately 245-acres. The remaining acreage on Rikers Island could support both:

1. 40.8-acres for 6,000 of MW OSW converter stations paired with a 28-acre 840 MW/3,360 MWh front-of-meter battery storage system to limit curtailment, and
2. 9 MW of behind-the-meter solar and 9 MW/53 MWh of behind-the-meter battery storage to serve as a power source for the WRRF.

Scenario 5 analysis did not consider potential solar PV and storage installation within the perimeter of the WRRF's footprint and is, therefore, likely a conservative estimate of solar generation and storage potential. There will likely be significant opportunities to install solar PV or storage on tanks, roofs, and parking areas.

4.7.1 Analyses of Benefits, Challenges, and Considerations

The 9 MW solar array[20] would help the offset WRRF's load, either from solar power generation or from storage in the 9 MW / 53 MWh behind-the-meter battery system. The added capacity of the converter stations and solar array would produce enough energy annually to avoid about 7,632,632 tons of atmospheric CO_2 emissions, equivalent to 1.7 million cars off the road.

DEP estimates the proposed new WRRF facility at Rikers Island would consume approximately 214,700 MWh of electricity each year, 5.6% of which could be offset by the behind-the-meter battery storage and solar. However, the facility's electricity rates would likely be on a "Time of Day" (TOD) rate schedule, where energy costs vary depending on the time of day.

[20] The REopt tool was used to determine optimal battery storage size for this scenario by constraining the maximum solar system size to 9 MW. Refer to Appendix C for details on the analysis assumptions and outputs.

4.7.2 Jobs and Economic Development Impacts

In Scenario 5, construction of energy infrastructure (which does not include the WRRF but includes the behind-the-meter battery storage and solar that would help power the WRRF) would support an estimated 848 jobs, with 351 installing battery storage, 456 supporting the construction of the OSW converter stations, and 41 jobs installing solar. The total economic impact of worker aggregate earnings, the total economic activity across industries and workers, and GDP are estimated to be $91.5 million; $176.1 million; and $120.9 million respectively. The initial construction cost per MW associated with Scenario 5 is $308,907.

Table 16. Scenario 5 Initial Construction Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (9 MW)	41	$3.2	$6.2	$4.6
Battery Storage (849 MW)	351	$47.3	$105.5	$65.8
OSW Converter Stations (6,000 MW)	456	$41	$64.4	$50.5
Total	**848**	**$91.5**	**$176.1**	**$120.9**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 5's O&M is estimated to create 225 long-term jobs, including impacts across on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. The economic impacts of O&M include $16.8 million in thousands of workers' earnings; $52.3 million in total added economic output across all industries and workers, and $31.5 million in GDP. Scenario 5's annual system O&M costs per MW would be $24,494.

Table 17. Scenario 5 Annual System O&M Impacts

Technology	Jobs	Earnings	Output	GDP
Solar (9 MW)	2	$0.14	$0.24	$0.19
Battery Storage (849 MW)	165	$15.2	$47.6	$29
OSW Converter Stations (6,000 MW)	58	$1.5	$4.7	$2.3
Total	**225**	**$16.8**	**$52.3**	**$31.5**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

5. Conclusion & Next Steps

Achieving New York City and State's clean energy goals over the next 30 years will require a massive effort to convert fossil fuel generated building systems and equipment in the city—including hot water boilers and water heaters, gas stoves, and millions of vehicles—to run on electricity. Additionally, the electricity that powers New York City must be generated exclusively by clean sources. Given the extreme shortage of available land in New York City's densely populated urban environment, harnessing hundreds of acres of available buildable land presents a good opportunity to help achieve the State's and City's clean energy goals.

This report examined five different scenarios with different combinations of clean energy technologies for deployment on Rikers Island. Scenario 4 would introduce more generation capacity (at 12,000 MW) than New York City's grid is currently prepared to absorb. While Scenarios 1 through 3 are viable, Scenario 5 presents a long-term vision to maximize the isolated land on Rikers Island for a diverse array of renewable energy and wastewater infrastructure. This is a compelling alternative to the current antiquated energy and wastewater infrastructure that is located close to New Yorkers' neighborhoods.

Box 3. Next Steps

Topic Area	Action Item(s)
Master Planning	To develop any of the feasible scenarios, a master plan should explore the following: • *WRRF*: Opportunities to increase biogas exports with organics co-digestion; necessary infrastructure for gas-to-grid program success; and estimating potential of solar and storage integration with a new WRRF. • *Surface Elevation*: Should the surface elevation of Rikers Island be elevated with fill or should infrastructure itself be elevated? Should the buildable acreage be larger? • *Governance Structures*: What governance structures has New York City used to develop large parcels of land (e.g., development corporations)? Which of these mechanisms is best suited for Rikers Island? Which city agencies have jurisdiction over projects on Rikers Island? • *Co-location*: Whether energy infrastructure can be co-located with other uses, such as urban agriculture, composting facilities or a major EV charging hub to support both public and private vehicles.

Discrete Studies	• *Transmission*: The city must account for and determine the landfall rating for any transmission cables used to deliver OSW energy to Rikers Island. The landfall rating is a capacity limitation placed on transmission cables at points of interconnection to provide a contingency if cables stop operating. The landfall rating is a necessary consideration regardless of the cable type chosen (i.e., AC, DC, HVDC, HVAC) as it impacts whether and at what level infrastructure can interconnected to an existing point. Additionally, electric infrastructure capacity and the ability to transmit power from Rikers Island into the electric grid, including potential points of interconnection and related costs must be examined. • *OSW*: Future analysis and planning to determine the level of OSW energy that can flow through Rikers Island must consider the largest loss-of-source contingency. This is an operational limit set by the NYISO designed to ensure that, should the state's largest source of power be offline, there is sufficient additional capacity to prevent a cascade of grid disruptions.[21]

[21] In New York State, the largest loss-of-source contingency is 1,310 MW, the size of the current largest electricity generation source feeding New York's grid. The contingency requires that each increment of 1,310 MW be interconnected to the grid at a different transmission substation. While those substations can be sited adjacent to or near each other, this requirement imposes limitations on the design and capacity of energy infrastructure that is essential to consider in future master planning.

Appendix A. Jobs & Economic Development Analysis Details

The analysis presents two sets of impacts: (1) initial construction, which reflects the one-time, duration-limited benefits for the installation of the clean energy systems; and (2) the annual impacts derived from the systems' O&M impacts for the entirety of the systems' lifespan. All five scenarios utilize gross overall economic impacts for the construction phase, based on NREL's Annual Technology Baseline (ATB)[22] technological default cost assumptions. These values were then modified with New York City-specific cost indices to account for New York City's unionized labor.

A.1 Scenario 1 Analysis

A.1.1 Scenario 1: Solar

Table A.1 shows the total economic impacts for the construction of 110 MW of solar on Rikers Island. Scenario 1 solar construction supports a total estimated 365 direct jobs. Of this total, there are an estimated 266 jobs for on-site construction and development work and 99 for construction and installation related services. Initial construction would also support 190 jobs for supply-chain related industries in manufacturing, trade, finance, professional services, and local revenue. Expenditures made by onsite and supply chain workers in New York support an additional 118 induced jobs.

Table A.1. Scenario 1 Solar Construction Phase Impacts

Construction & Installation Phase	Jobs	Earnings	Output	GDP
Project Development & Onsite Labor Impacts				
Construction & Installation Labor	266	$20.7		
Construction & Installation Related Services	99	$9.1		
Subtotal	**365**	**$29.7**	**$40.2**	**$34.6**
Module $ Supply Chain Impacts				
Manufacturing	0	$0	$0	$0
Trade (Wholesale & Retail)	16	$1.2	$4.1	$2.5
Finance, Insurance & Real Estate	0	$0	$0	$0
Professional Services	24	$1.8	$5.3	$3.5
Other Services	30	$4.4	$11.8	$7.7
Other Sectors	120	$7.2	$15.2	$10.4
Subtotal	**190**	**$14.6**	**$36.4**	**$24.1**
Impacts	118	$7.6	$24.8	$15.7
Total Impacts	**673**	**$51.9**	**$101.4**	**$74.4**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

[22] Each year, NREL provides a robust set of modeling input assumptions for energy technologies to inform electric and transportation sector analysis. This is the "Annual Technology Baseline." https://atb.nrel.gov.

The Scenario 1 solar allocation is estimated to support 24 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.2 shows the annual jobs supported in each category. There are 17 on-site job positions directly involved with maintaining the solar arrays. The analysis also estimates that approximately four O&M annual jobs are supported from local revenue, and supply chain related impacts. Expenditures made by on-site and supply chain workers support an additional three induced jobs.

Table A.2. Scenario 1 Solar O&M Impacts				
During Operating Years	Jobs	Earnings	Output	GDP
Onsite Labor Impacts				
Solar Project Labor Only	17	$1.2	$1.2	$1.2
Local Revenue & Supply Chain Impacts	4	$0.4	$1.2	$0.8
Impacts	3	$0.1	$0.5	$0.3
Total Impacts	**24**	**$1.7**	**$3**	**$2.3**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars. Construction and operating period jobs are for one year (2,080 hours). Economic impacts "during operating years" represent impacts that occur from system/ plant operations/ expenditures. Totals may not add up due to independent rounding.

A.1.2 Scenario 1: Front-of-Meter Battery Storage

Scenario 1 battery storage construction supports an estimated 168 jobs, as shown in Table A.3. Of these, 55 were on-site workers directly involved in construction and development. Meanwhile, battery storage construction supports 85 jobs for on-site construction, supply chain workers, subcomponent manufacturing workers, construction subcontractors, and professional contractors, such as accountants and lawyers. Expenditures made by onsite and supply chain workers in New York support an additional 28 induced jobs.

Table A.3. Scenario 1 Battery Storage Construction Phase Impacts				
Construction Phase	Jobs	Earnings	Output	GDP
Onsight	55	$4.8	$16.1	$10.4
Supply Chain	85	$15.1	$26.2	$15.9
Impacts	28	$2.6	$8.1	$5.2
Total	**168**	**$22.6**	**$50.3**	**$31.4**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 1's front-of-meter battery storage production is estimated to support 158 long-term jobs. Table A.4 shows the annual jobs supported in each category. 85 jobs are on-site positions directly involved with maintaining the battery storage on Rikers Island each year. Under Scenario 1, results approximate 38 O&M annual jobs are supported from local revenue, turbine, and supply chain. Expenditures made by on-site and supply chain workers support an additional 36 annual induced jobs.

Table A.4. Scenario 1 Battery Storage O&M Annual Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Onsight	85	$7.2	$21.6	$14.6
Supply Chain	38	$4.1	$13.8	$6.6
Impacts	36	$3.2	$10.1	$6.5
Total	**158**	**$14.5**	**$45.5**	**$27.7**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.2 Scenario 2 Analysis

A.2.1 Scenario 2: Solar

Scenario 2 solar construction supports an estimated 593 jobs. From this grand total, 234 jobs were on-site workers directly involved in construction and development, while 87.6 were from construction and installation related services. The grand total jobs include another 167.2 jobs for supply-chain related industries in manufacturing, trade, finance, professional services, and local revenue decomposed to their individual sub-sections below in Table A.5. Expenditures made by onsite and supply chain workers support 104 induced jobs.

Table A.5. Scenario 2 Solar Construction Phase Impacts				
Construction & Installation Phase	Jobs	Earnings	Output	GDP
Project Development & Onsite Labor Impacts				
Construction & Installation Labor	234	$18.2		
Construction & Installation Related Services	87.6	$7.8		
Subtotal	**322**	**$26**	**$35.4**	**$30.5**
Module $ Supply Chain Impacts				
Manufacturing	0	$0	$0	$0
Trade (Wholesale & Retail)	14	$1.1	$3.6	$2.2
Finance, Insurance & Real Estate	0	$0	$0	$0
Professional Services	21	$1.6	$4.7	$3
Other Services	27	$3.9	$10.4	$6.8
Other Sectors	106	$6.3	$13.4	$9.2
Subtotal	**167**	**$12.9**	**$32.1**	**$21.2**
Impacts	104	$6.9	$21.9	$13.8
Total	**593**	**$45.8**	**$89.4**	**$65.5**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 2's solar allocation is estimated to support 21 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.6 shows the annual jobs supported in each category. A total of 15 jobs are on-site positions directly involved with maintaining the solar arrays. Results also estimate approximately 4 O&M annual jobs are supported from local revenue, and supply chain related impacts. Lastly, expenditures made by on-site and supply chain workers support an additional two induced jobs.

Table A.6. Scenario 2 Solar O&M Impacts

During Operating Years	Jobs	Earnings	Output	GDP
Onsite Labor Impacts				
Solar Project Labor Only	15	$1.1	$1.1	$1.1
Local Revenue & Supply Chain Impacts	4	$30.3	$1.1	$0.6
Impacts	3	$0.1	$0.4	$0.3
Total	**21**	**$1.5**	**$2.6**	**$2**

Notes: All dollar values are in approximate millions of 2050 U.S. dollars.

A.2.2 Scenario 2: Front-of-Meter Battery Storage

Scenario 2 battery storage construction supports an estimated 38 jobs, as shown in Table A.7. Of these, 15 were on-site workers directly involved in construction and development; 18 jobs for on-site construction, supply chain workers, subcomponent manufacturing workers, construction subcontractors, and professional contractors, such as accountants and lawyers. Expenditures made by onsite and supply chain workers support an additional six induced jobs in New York.

Table A.7. Scenario 2 Battery Storage Construction Phase Impacts

Construction Phase	Jobs	Earnings	Output	GDP
Onsight	15	$1.3	$4.3	$2.8
Supply Chain	18	$3.1	$4.7	$3.3
Impacts	6	$0.1	$1.7	$1.1
Total	**38**	**$5**	**$10.7**	**$7.2**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Based on the model results, Scenario 2's front-of-meter battery storage production is estimated to support 31 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.8 shows the annual jobs supported in each category. A total of 17 jobs are on-site positions directly involved with maintaining battery storage. Under the model, Scenario 2 results estimate an approximate total of seven O&M annual jobs supported from local revenue, turbine, and supply chain. Expenditures made by on-site and supply chain workers support an additional seven induced jobs.

Table A.8. Scenario 2 Battery Storage O&M Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Onsight	17	$1.4	$4.4	$2
Supply Chain	7	$0.8	$2.7	$1.3
Impacts	7	$0.6	$1.9	$1.3
Total	**31**	**$2.9**	**$9**	**$5.5**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.2.3 Scenario 2: 4,000 MW Offshore Wind Converter Stations

Scenario 2 OSW converter station construction supports an estimated 304 jobs, as shown in Table A.9. A total of 162 jobs were on-site workers directly involved in construction and 48 jobs for supply chain-related services for the installation of OSW converter stations. Expenditures made by onsite and supply chain workers support an additional 94 induced jobs in New York.

Table A.9. Scenario 2 OSW Converter Stations Construction Phase Impacts				
Construction Phase	Jobs	Earnings	Output	GDP
Technicians & Management	162	$17.1	$17.1	$17.1
Supply Chain & Support Services	48	$3.2	$8.3	$5.2
Impacts	94	$7.0	$17.5	$11.4
Total	**304**	**$27.3**	**$43**	**$33.7**

Notes: All dollar values are in approximate millions of 2050 U.S. dollars.

Based on the model results, Scenario 2's front-of-meter battery storage production is estimated to support 31 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.8 shows the annual jobs supported in each category. A total of 17 jobs are on-site positions directly involved with maintaining battery storage. Under the model, Scenario 2 results estimate an approximate total of seven O&M annual jobs supported from local revenue, turbine, and supply chain. Expenditures made by on-site and supply chain workers support an additional seven induced jobs.

Table A.10. Scenario 2 OSW Converter Stations O&M Annual Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Technicians & Management	26	$0.1	$0.1	$0.1
Supply Chain & Support Services	10	$0.7	$2.5	$1.2
Impacts	3	$0.2	$0.5	$0.3
Total	**39**	**$1.0**	**$3.1**	**$1.6**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.3 Scenario 3 Analysis

A.3.1 Scenario 3: Solar

Scenario 3 solar construction supports an estimated 456 jobs as shown in Table A.11. From this grand total, 200 jobs were on-site workers directly involved in the project's construction and development and 62 were from construction and installation related services. The grand total jobs include another 119.1 jobs for supply-chain related industries in manufacturing, trade, finance, professional services, and local revenue. Expenditures made by onsite and supply chain workers support an additional 74.1 induced jobs in New York.

Table A.11. Scenario 3 Solar Construction Phase Impacts

Construction & Installation Phase	Jobs	Earnings	Output	GDP
Project Development & Onsite Labor Impacts				
Construction & Installation Labor	200	$13		
Construction & Installation Related Services	62	$5.7		
Subtotal	**263**	**$18.7**	**$25,237**	**$21.7**
Module $ Supply Chain Impacts				
Manufacturing	0	$0	$0	$0
Trade (Wholesale & Retail)	10	$0.8	$2.5	$1.6
Finance, Insurance & Real Estate	0	$0	$0	$0
Professional Services	15	$1.1	$3.3	$2.1
Other Services	19	$2.8	$7.5	$4.8
Other Sectors	75	$4.5	$9.6	$6.6
Subtotal	**119**	**$9.2**	**$22.9**	**$15.1**
Impacts	74	$4.7	$15.6	$9.9
Total	**456**	**$32.6**	**$63.7**	**$46.7**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 3's solar allocation is estimated to support 23 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.12 shows the annual jobs supported in each category. A total of 17 jobs are on-site positions directly involved with maintaining the solar arrays. Additionally, the study estimates approximately three O&M annual jobs are supported by local revenue, and supply chain related impacts. Expenditures made by on-site and supply chain workers support an additional two induced jobs.

Table A.12. Scenario 3 Solar O&M Impacts

During Operating Years	Jobs	Earnings	Output	GDP
Onsite Labor Impacts				
Solar Project Labor Only	15	$1	$1	$1
Local Revenue & Supply Chain Impacts	3	$0.3	$1	$0.6
Impacts	3	$0.2	$0.5	$0.3
Total	**21**	**$1.5**	**$2.5**	**$1.9**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.3.2 Scenario 3: Front-of-Meter Battery Storage

Scenario 3 battery storage construction supports an estimated 327 jobs, as shown in Table A.13. Of these, 165 were on-site workers directly involved in the project's construction and development. The 327 jobs also include 165 jobs for supply chain workers, subcomponent manufacturing workers, construction subcontractors, and professional contractors, such as accountants and lawyers. Expenditures made by onsite and supply chain workers support an additional 55 induced jobs.

Table A.13. Scenario 3 Battery Storage Construction Phase Impacts

Construction Phase	Jobs	Earnings	Output	GDP
Onsight	107	$9.5	$31.4	$20.2
Supply Chain	165	$29.5	$51	$30.9
Impacts	55	$5	$15.7	$10.1
Total	**327**	**$44**	**$98.1**	**$61.2**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 3's front-of-meter battery storage production is estimated to support 154 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. shows the annual jobs supported in each category. Of these, 83 jobs are on-site positions directly involved with maintaining the battery storage site. The model estimates approximately 36 O&M annual jobs are supported from local revenue and supply chain. Expenditures made by on-site and supply chain workers support an additional 35 induced jobs.

Table A.14. Scenario 3 Battery Storage O&M Annual Impacts

O&M Phase	Jobs	Earnings	Output	GDP
Onsight	83	$7	$21.2	$14.3
Supply Chain	36	$4	$13.3	$6.4
Impacts	35	$3.2	$9.8	$6.3
Total	**154**	**$14.2**	**$44.3**	**$27**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.3.3 Scenario 3: 6,000 MW Offshore Wind Converter Stations

Scenario 3 OSW converter stations construction supports an estimated 456 jobs, as shown in Table A.15. A total of 244 jobs were on-site workers directly involved in construction and 71 jobs for supply chain related services for the installation of OSW converter stations. Expenditures made by onsite and supply chain workers support an additional 142 induced jobs.

Table A.15. Scenario 3 OSW Converter Stations Construction Phase Impacts				
Construction Phase	Jobs	Earnings	Output	GDP
Technicians & Management	244	$25.6	$25.6	$25.6
Supply Chain & Support Services	71	$4.9	$12.5	$7.8
Impacts	142	$10.5	$26.3	$17.1
Total	**456**	**$41**	**$64.4**	**$50.5**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 3's OSW converter stations are estimated to support 58 long-term jobs annually during operating years. Table A.16 shows the annual jobs supported in each category. Of these, 38 jobs are on-site positions directly involved with maintaining the OSW converter station. These positions include wind technicians, managers, administrative professionals, and other workers. Results estimate approximately 15 O&M annual jobs are supported from supply chain related services. Expenditures made by on-site and supply chain workers support an additional five induced jobs.

Table A.16. Scenario 3 OSW Converter Stations O&M Annual Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Technicians & Management	38	$0.1	$0.1	$0.1
Supply Chain & Support Services	15	$1.1	$3.8	$1.7
Impacts	5	$0.3	$0.8	$0.5
Total	**58**	**$1.5**	**$4.7**	**$2.3**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.4 Scenario 4 Analysis

A.4.1 Scenario 4: Solar

Scenario 4 solar construction supports an estimated 298 jobs as shown in Table A.17. From this grand total, 118 jobs were on-site workers directly involved in the project's construction and development and 44.1 were from construction and installation related services. The grand total jobs include another 84 jobs for supply-chain related industries in manufacturing, trade, finance, professional services, and local revenue. Expenditures made by onsite and supply chain workers support an additional 52 induced jobs in New York.

Table A.17. Scenario 4 Solar Construction Phase Impacts

Construction & Installation Phase	Jobs	Earnings	Output	GDP
Project Development & Onsite Labor Impacts				
Construction & Installation Labor	118	$9.1		
Construction & Installation Related Services	44	$4		
Subtotal	**164**	**$13.1**	**$17.8**	**$15.3**
Module $ Supply Chain Impacts				
Manufacturing	0	$0	$0	$0
Trade (Wholesale & Retail)	7	$0.6	$1.8	$1.1
Finance, Insurance & Real Estate	0	$0	$0	$0
Professional Services	11	$0.8	$2.4	$1.5
Other Services	13	$1.9	$5.2	$3.4
Other Sectors	53	$3.2	$6.7	$4.7
Subtotal	**84**	**$6.5**	**$16.1**	**$10.7**
Impacts	52	$3.4	$11.1	$7
Total	**298**	**$23**	**$45**	**$33**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 4's solar allocation is estimated to support 14 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.18 shows the annual jobs supported in each category. Of these, ten jobs are on-site positions directly involved with maintaining the solar arrays. These positions include technicians, managers, administrative professionals, and other workers. Analysis estimates approximately two O&M annual jobs are supported from local revenue, and supply chain related impacts. Expenditures made by on-site and supply chain workers support an additional two induced jobs.

Table A.18. Scenario 4 Solar O&M Impacts				
During Operating Years	Jobs	Earnings	Output	GDP
Onsite Labor Impacts				
Solar Project Labor Only	10	$0.7	$0.7	$0.7
Local Revenue & Supply Chain Impacts	2	$0.2	$0.7	$0.4
Impacts	2	$0.1	$0.4	$0.3
Total	**14**	**$1**	**$1.8**	**$1.4**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.4.2 Scenario 4: Behind-the-Meter Battery Storage

Scenario 4 battery storage construction supports an estimated 385 jobs, as shown in Table A.19. Of these, 114 were on-site workers directly involved in the project's construction and development. It also includes 201 jobs for supply chain workers, subcomponent manufacturing workers, construction subcontractors, and professional contractors, such as accountants and lawyers. Expenditures made by onsite and supply chain workers support an additional 71 induced jobs.

Table A.19. Scenario 4 Battery Storage Construction Phase Impacts				
Construction Phase	Jobs	Earnings	Output	GDP
Onsight	114	$10.1	$34.2	$21.8
Supply Chain	201	$36.5	$66.2	$38.9
Impacts	71	$6.5	$20.2	$12.9
Total	**385**	**$53.1**	**$120.6**	**$73.6**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 4's front-of-meter battery storage production is estimated to support 114 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.20 shows the annual jobs supported in each category. A total of 59 jobs are on-site positions directly involved with maintaining the battery storage site. Analysis also estimates that approximately 28 O&M annual jobs are supported from local revenue and supply chain. Expenditures made by on-site and supply chain workers support an additional 25 induced jobs.

Table A.20. Scenario 4 Battery Storage O&M Annual Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Onsight	59	$5	$15.1	$10.3
Supply Chain	28	$3.1	$10.5	$4.9
Impacts	25	$2.3	$7.2	$4.6
Total	**113**	**$10.4**	**$32.8**	**$19.8**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.4.3 Scenario 4: 12,000 MW Offshore Wind Converter Stations

Scenario 4 high OSW converter station construction supports an estimated 913 jobs, as shown in Table A.21. A total of 487 jobs were on-site workers directly involved in construction and 143 jobs for supply chain related services for the installation of OSW converter stations. Expenditures made by onsite and supply chain workers support an additional 283 induced jobs in New York.

Table A.21. Scenario 4 OSW Converter Stations Construction Phase Impacts

Construction Phase	Jobs	Earnings	Output	GDP
Technicians & Management	487	$51.2	$51.2	$51.2
Supply Chain & Support Services	143	$9.8	$25	$15.6
Impacts	283	$21.1	$52.6	$34.2
Total	**913**	**$82**	**$128.9**	**$101**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 4's OSW converter stations are estimated to support 116 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.22 shows the annual jobs supported in each category. A total of 77 jobs are on-site positions directly involved with maintaining the converter stations. Analysis also estimates that approximately 30 O&M annual jobs are supported from local revenue, turbine, and supply chain. Expenditures made by on-site and supply chain workers support an additional nine jobs.

Table A.22. Scenario 4 OSW Converter Stations O&M Annual Impacts

O&M Phase	Jobs	Earnings	Output	GDP
Technicians & Management	77	$0.2	$0.2	$0.2
Supply Chain & Support Services	30	$2.2	$7.6	$3.4
Impacts	9	$0.6	$1.6	$1
Total	**116**	**$3**	**$9.3**	**$4.7**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.5 Scenario 5 Analysis

A.5.1 Scenario 5: Solar

Scenario 5 solar construction supports an estimated 41 jobs, as shown in Table A.23. From this grand total, 16 jobs were on-site workers directly involved in the project's construction and development and six were from construction and installation related services. The grand total jobs include another 12 jobs for supply-chain related industries in manufacturing, trade, finance, professional services, and local revenue. Expenditures made by onsite and supply chain workers support an additional seven induced jobs.

Table A.23. Scenario 5 Solar Construction Phase Impacts

Construction & Installation Phase	Jobs	Earnings	Output	GDP
Project Development & Onsite Labor Impacts				
Construction & Installation Labor	16	$1.3		
Construction & Installation Related Services	6	$0.6		
Subtotal	**22**	**$1.8**	**$2.5**	**$2.1**
Module $ Supply Chain Impacts				
Manufacturing	0	$0	$0	$0
Trade (Wholesale & Retail)	1	$0.08	$0.3	$0.2
Finance, Insurance & Real Estate	0	$0	$0	$0
Professional Services	2	$0.1	$0.3	$0.2
Other Services	2	$0.3	$0.7	$0.5
Other Sectors	7	$0.4	$0.9	$0.6
Subtotal	**12**	**$0.9**	**$2.2**	**$1.5**
Impacts	7	$0.5	$1.5	$1
Total	**41**	**$3.2**	**$6.2**	**$4.6**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Based on the feasibility study results, Scenario 5's solar is estimated to support 1.9 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.24 shows the annual jobs supported in each category. A total of 1.4 jobs are on-site positions directly involved with maintaining the solar arrays. Analysis estimates that approximately 0.3 O&M annual jobs are supported by local revenue, and supply chain related impacts. Expenditures made by on-site and supply chain workers support an additional 0.2 induced jobs in unrelated industries that provide local services or goods.

Table A.24. Scenario 5 Solar O&M Impacts				
During Operating Years	Jobs	Earnings	Output	GDP
Onsite Labor Impacts				
Solar Project Labor Only	1.4	$0.1	$0.1	$0.1
Local Revenue & Supply Chain Impacts	0.3	$0.03	$0.1	$0.06
Impacts	0.2	$0.01	$0.04	$0.03
Total	**1.9**	**$0.14**	**$0.24**	**$0.19**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.5.2 Scenario 5: Front-of-Meter Battery Storage

Scenario 5 battery storage construction supports an estimated 351 jobs, as shown in Table A.25. Of these, 115 were on-site workers directly involved in the project's construction and development. It also includes 177 jobs for supply chain workers, subcomponent manufacturing workers, construction subcontractors, and professional contractors, such as accountants and lawyers. Expenditures made by onsite and supply chain workers support an additional 60 induced jobs.

Table A.25. Scenario 5 Battery Storage Construction Phase Impacts				
Construction Phase	Jobs	Earnings	Output	GDP
Onsight	115	$10.2	$33.7	$21.7
Supply Chain	177	$31.7	$54.8	$33.2
Impacts	60	$5.4	$17	$10.9
Total	**351**	**$47.3**	**$105.5**	**$65.8**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 5's front-of-meter battery storage production is estimated to support 165 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.26 shows the annual jobs supported in each category. Of these, 89 are on-site positions directly involved with maintaining the battery storage systems. Analysis estimates that approximately 39 O&M annual jobs are supported by local revenue and supply chain. Expenditures made by on-site and supply chain workers support an additional 37 induced jobs.

Table A.26. Scenario 5 Battery Storage O&M Annual Impacts				
O&M Phase	Jobs	Earnings	Output	GDP
Onsight	89	$7.6	$22.7	$15.4
Supply Chain	39	$4.2	$14.3	$6.8
Impacts	37	$3.4	$10.6	$6.8
Total	**165**	**$15.2**	**$47.6**	**$29**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

A.5.3 Scenario 5: 6,000 MW Offshore Wind Converter Stations

Scenario 5 OSW converter station construction supports an estimated 456 jobs, as shown in Table A.27. A total of 244 jobs were on-site workers directly involved in the project's construction and 71 jobs for supply chain related services for the installation of OSW converter stations. Expenditures made by on-site and supply chain workers support an additional 142 induced jobs.

Table A.27. Scenario 5 OSW Converter Stations Construction Phase Impacts

Construction Phase	Jobs	Earnings	Output	GDP
Technicians & Management	244	$25.6	$25.6	$25.6
Supply Chain & Support Services	71	$4.9	$12.5	$7.8
Impacts	142	$10.5	$26.3	$17.1
Total	**456**	**$41**	**$64.4**	**$50.5**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Scenario 5's OSW converter stations are estimated to support 58 long-term jobs annually during operating years, which includes on-site O&M workers, supporting business and supply chain jobs, and employment supported through induced impacts. Table A.28 shows the annual jobs supported in each category. A total of 38 jobs are on-site positions directly involved with maintaining the converter stations. The feasibility study also estimates that approximately 15 O&M annual jobs are supported from local revenue, turbine, and supply chain. Expenditures made by on-site and supply chain workers support an additional five jobs.

Table A.28. Scenario 5 OSW Converter Stations O&M Annual Impacts

O&M Phase	Jobs	Earnings	Output	GDP
Technicians & Management	56	$4.5	$4.5	$4.5
Supply Chain & Support Services	155	$21.5	$12.5	$33.1
Impacts	107	$7.6	$26.3	$13.2
Total	**319**	**$34**	**$64.4**	**$51**

Notes: All dollar values are in approximate millions of 2023 U.S. dollars.

Appendix B. WRRF Analysis

B.1 Current & Future WRRF Load Profiles

Figure 9 shows the load profile[23] of all four current WRRFs the new facility on Rikers Island would replace.

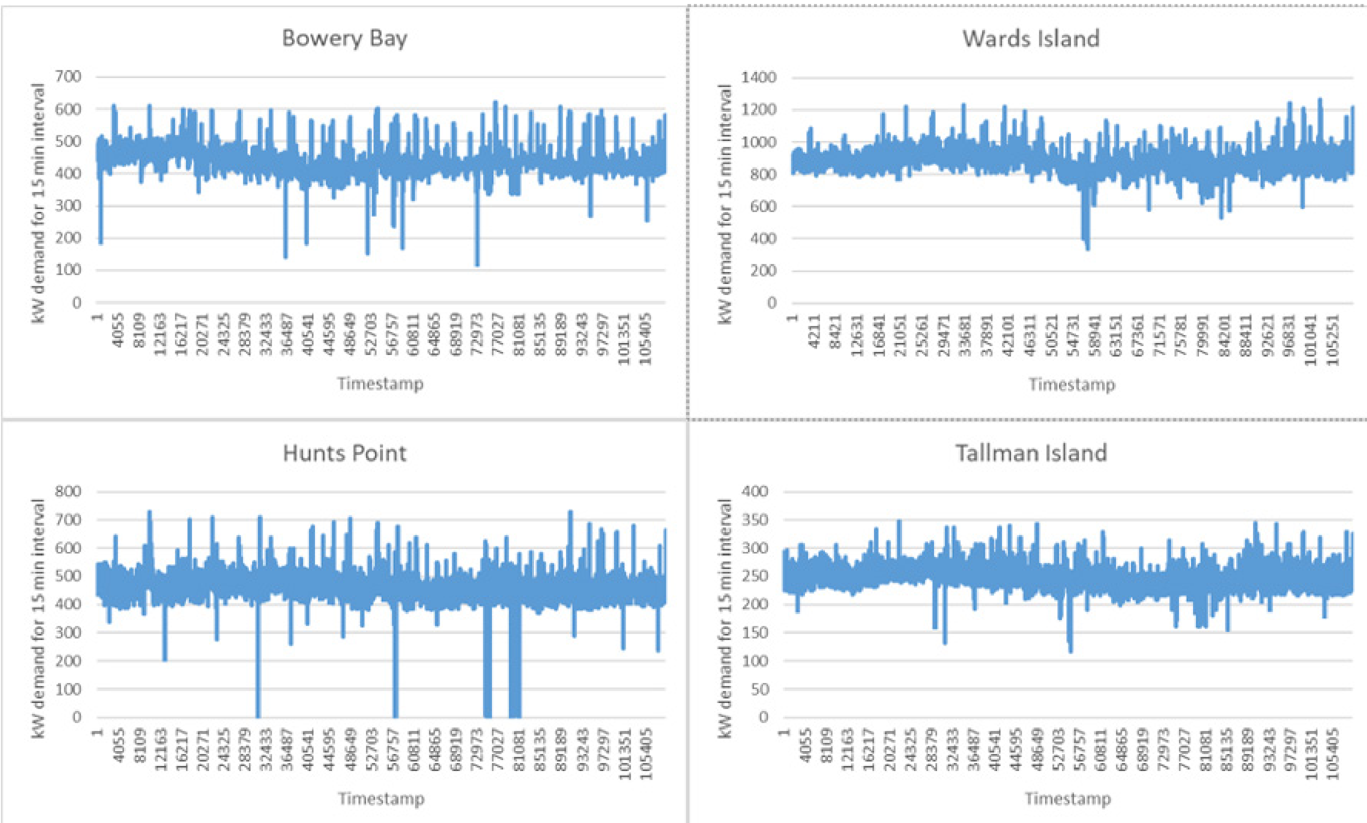


Figure 9. Load profiles of four existing New York City WRRFs to be consolidated by a Rikers Island WRRF.

Figure 10 shows the aggregated load profile (combining the four existing ones) of the proposed WRRF at Rikers Island.

[23] Missing values were populated with averages of the previous and next timestamp. Anomalies were removed.

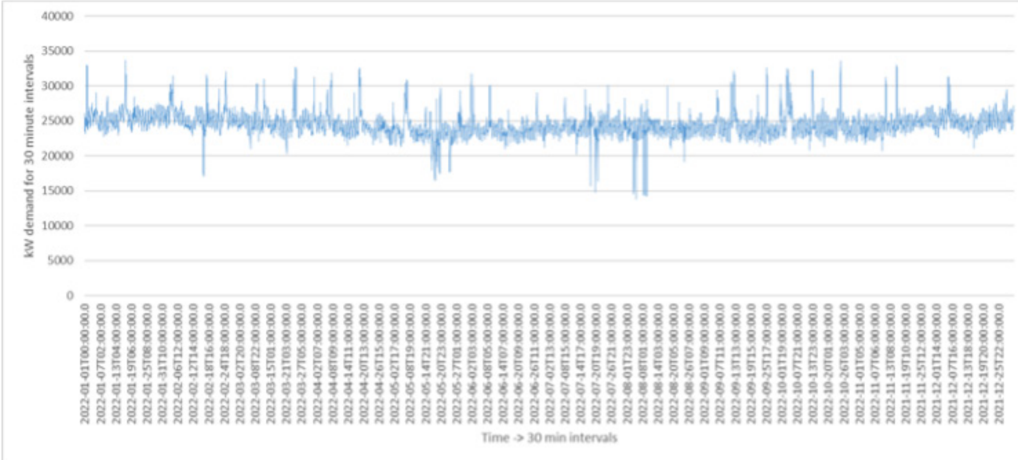


Figure 10. Aggregated load profile of the four above WRRFs, to approximate new WRRF's load.

B.2 REopt Assumptions and Results

Table B.1. REopt Analysis Critical Assumptions

Parameters	Value	Source
Installation Year	2027	MOCEJ
Solar CAPEX ($)	$2.67/watt	ATB: 0.891 $/WDC City Multiplier (RS Means): 3.52 + Union labor (x 1.2) =$2.673 per Watt (2027)
Solar O&M Cost	$24.18/kW	$24.18/kW ATB: $20.147 City Multiplier: 3.52 + Union labor (x 1.2) =$24.18 /kW per year (2027)
Battery Storage CAPEX ($)	$119.218/kW $336.423/kWh	NYSCAC Scoping Plan (Dec. 19, 2022) https://climate.ny.gov/resources/scoping-plan (2027)
Battery Storage 10-year Replacement Cost	59.609/kW 168.212/kWh	Half of what is assumed as the Initial CAPEX (REopt)
Solar Charging the Battery Storage	TrueC	MOCEJ
Grid Charging the Battery Storage	False	MOCEJ
Analysis Period (Years)	25 Years	MOCEJ
ITC (%)	30%	IRA, 2022
Discount Rate, nominal (%)	2.55%	New York City's Office of Management & Budget
Rikers Island WRRF Rate Schedule	Service Class 98-TOD	DEP

Table B.2. REopt Results: Scenario 5 Behind-the-Meter Battery Storage & Solar Analysis		
Parameters	Business As Usual Case (No Battery Storage + Solar)	Fixed Solar + Optimal Battery Storage
Solar Size (MW)	Not Applicable	9 MW
Year 1 Solar Production (MWh)	Not Applicable	11,833.11 MWh
Battery Storage Power (MW)	Not Applicable	9.44 MW
Battery Storage Capacity (MWh)	Not Applicable	53.3 MWh
Average Annual Energy Supplied from the Grid (MWh)	214,676 MWh	204,402 MWh
Year 1 Utility Electricity Cost		
Utility Energy Cost ($)	$14,623,800	$13,883,000
Utility Demand Cost ($)	$19,501,750	$15,571,950
Total Year 1 Utility Cost ($)	$34,125,550	$29,454,950
Lifecycle Utility Electricity Cost		
Utility Energy Cost ($)	$336,945,000	$319,874,000
Utility Demand Cost ($)	$449,335,100	$358,789,500
Total Year 1 Utility Cost ($)	$786,280,100	$678,663,500
Summary Financial Metrics		
Solar Capex ($) before incentives	Not Applicable	$24,057,000
Battery Storage Capex ($) Before Incentives	Not Applicable	$19,058,161
Total Upfront Capital Cost ($) Before Incentives	Not Applicable	$43,115,161
Total Lifecycle O&M Cost ($)	Not Applicable	$5,406,151
Replacement Cost of Battery Storage ($)	Not Applicable	$7,407,888
Total Lifecycle Cost ($)	$786,280,100	$721,978,758
Net Present Value ($) When Compared to BAU	Not Applicable	$64,301,342

Appendix C. Footprint Calculations

Table C.1. Scenario 1 Solar & Battery Storage Footprint			
Parameters	Value	Notes / Calculations	Source
Rikers Island Total Footprint (acres)	413 acres		MOCEJ/DEP
Area Lost Due to Sea Level Rise (acres)	51.55 acres		GIS Analysis
Buffer (Access Road, easements, lines, etc.; acres)	18.07 acres	= 5% of (413 - 51.55 acres)	Conservative Estimate; NREL
Available Footprint (acres)	343.38 acres	= 413 - 1.55 - 18.07	
Solar Capacity (MW_{dc})	110 MW_{dc}	3 acres/ MW_{dc}	Helioscope Modeling (NYPA and NREL) and LBNL report
Available Ground Mount Solar Area (acres)	329.01 acres	= 343.38 - 14.37	
Battery Storage Power Capacity (MW)	431 MW		E3 Consulting
Battery Storage Energy Capacity (MWh)	1724 MWh		E3 Consulting
Battery Storage Footprint (acres)	14.37 acres	0.033 acres/MWac*	E3 Consulting

* Projects in urban environments require more space for each MW of battery storage due to additional safety requirements and other considerations. The standard space requirement is based on assessments of similar recent projects all for four-hour duration battery storage.[lxxxix]

Table C.2. Scenario 2 Solar, Battery Storage, & OSW Converter Stations Footprint			
Parameters	Value	Notes / Calculations	Source
Rikers Island Total Footprint (acres)	413 acres		MOCEJ/DEP
Area Lost Due to Sea Level Rise (acres)	51.55 acres		GIS Analysis
Buffer (Access Road, easements, lines, etc.; acres)	18.07 acres	= 5% of (413 - 51.55 acres)	Conservative Estimate; NREL
Available Footprint (acres)	343.38 acres	= 413 - 1.55 - 18.07	
Solar Capacity (MW_{dc})	104 MW_{dc}	3 acres/ MW_{dc}	Helioscope Modeling (NYPA and NREL) and LBNL report
Available Ground Mount Solar Area (acres)	312.20 acres	= 343.38 -14.37	
Battery Storage Power Capacity (MW)	120 MW		Power Gem
Battery Storage Energy Capacity (MWh)	480 MWh		Power Gem
Battery Storage Footprint (acres)	4 acres	0.033 acres/MW_{ac}*	E3 Consulting
OSW Capacity (GW)	4 GW		NREL
OSW Footprint (acres)	27.18 acres		NREL
Available Footprint After OSW (acres)	316.20 acres	= 343.38 - 27.18	

* The standard space requirement is based on assessments of similar recent projects all for four-hour duration battery storage.

Table C.3. Scenario 3 Solar, Battery Storage, & OSW Converter Stations Footprint			
Parameters	Value	Notes / Calculations	Source
Rikers Island Total Footprint (acres)	413 acres		MOCEJ/DEP
Area Lost Due to Sea Level Rise (acres)	51.55 acres		GIS Analysis
Buffer (Access Road, easements, lines, etc.; acres)	18.07 acres	= 5% of (413 - 51.55 acres)	Conservative Estimate; NREL
Available Footprint (acres)	343.38 acres	= 413 - 1.55 - 18.07	
Solar Capacity (MW_{dc})	92 MW_{dc}	3 acres/ MW_{dc}	Helioscope Modeling (NYPA and NREL) and LBNL report
Available Ground Mount Solar Area (acres)	274.60 acres	= 302.60 - 28	
Battery Storage Power Capacity (MW)	840 MW		Power Gem
Battery Storage Energy Capacity (MWh)	3,360 MWh		Power Gem
Battery Storage Footprint (acres)	28 acres	0.033 acres/MW_{ac}*	E3 Consulting
OSW Capacity (GW)	6 GW		NREL
OSW Footprint (acres)	40.78 acres		NREL
Available Footprint After OSW (acres)	302.60 acres	= 343.38 - 40.78	

* The standard space requirement is based on assessments of similar recent projects all for four-hour duration battery storage.

Table C.4. Scenario 4 Solar, Battery Storage, & OSW Converter Stations Footprint			
Parameters	**Value**	**Notes / Calculations**	**Source**
Rikers Island Total Footprint (acres)	413 acres		MOCEJ/DEP
Area Lost Due to Sea Level Rise (acres)	51.55 acres		GIS Analysis
Buffer (Access Road, easements, lines, etc.; acres)	18.07 acres	= 5% of (413 - 51.55 acres)	Conservative Estimate; NREL
Available Footprint (acres)	343.38 acres	= 413 - 1.55 - 18.07	
Solar Capacity (MW_{dc})	65 MW_{dc}	3 acres/ MW_{dc}	Helioscope Modeling (NYPA and NREL) and LBNL report
Available Ground Mount Solar Area (acres)	194.90 acres	= 248	
Battery Storage Power Capacity (MW)	1,600 MW		Power Gem
Battery Storage Energy Capacity (MWh)	6,400 MWh		Power Gem
Battery Storage Footprint (acres)	53.33 acres	0.033 acres/MW_{ac}*	E3 Consulting
OSW Capacity (GW)	14 GW		NREL
OSW Footprint (acres)	95.14 acres		NREL
Available Footprint After OSW (acres)	248.24 acres	= 343.38 - 95.14	

* The standard space requirement is based on assessments of similar recent projects all for four-hour duration battery storage.

Table C.5. Scenario 5 Solar, Battery Storage, OSW Converter Stations, & WRRF Footprint			
Parameters	Value	Notes / Calculations	Source
Rikers Island Total Footprint (acres)	413 acres		MOCEJ/DEP
Area Lost Due to Sea Level Rise (acres)	51.55 acres		GIS Analysis
Buffer (Access Road, easements, lines, etc.; acres)	18.07 acres	= 5% of (413 - 51.55 acres)	Conservative Estimate; NREL
Available Footprint (acres)	343.38 acres	= 413 - 1.55 - 18.07	
Solar Capacity (MW_{dc})	9 MW_{dc}	3 acres/ MW_{dc}	Helioscope Modeling (NYPA and NREL) and LBNL report
Available Ground Mount Solar Area (acres)	57.60 acres	= 302.60 - 245	
Battery Storage Power Capacity (MW)	840 MW		Power Gem
Battery Storage Energy Capacity (MWh)	3,360 MWh		Power Gem
Battery Storage Footprint (acres)	28 acres	0.033 acres/MW_{ac}*	E3 Consulting
OSW Capacity (GW)	6 GW		NREL
OSW Footprint (acres)	40.78 acres		NREL
Available Footprint After OSW (acres)	302.60 acres	= 343.38 - 40.78	
WRRF Footprint (acres)	245 acres		DEP
Available Footprint (acres) for Battery Stor-age & Solar After WRRF	29.60 acres	= 248.24 - 53.33	

* The standard space requirement is based on assessments of similar recent projects all for four-hour duration battery storage. As it pertains to solar capacity (MW_{dc}) — 9 MW of solar would occupy 27 acres. The remaining 2.7 acres would be used to install behind-the-meter battery storage and capacity would be optimally sized from the REopt.

List of Acronyms

AC	Alternating Current
CHPE	Champlain Hudson Power Express
CLCPA	Climate Leadership and Community Protection Act
Council	New York City Council
CO_2	Carbon Dioxide
CPNY	Clean Path New York
CSO	Combined Sewer Overflow
DACs	Disadvantaged Communities
DC	Direct Current
DCAS	New York City Department of Citywide Administration Services
DCP	New York City Department of City Planning
DEP	New York City Department of Environmental Protection
DOC	New York City Department of Corrections
EDC	New York City Economic Development Corporation
EIA	U. S. Energy Information Administration
EV	Electric Vehicle
FEMA	U.S. Federal Emergency Management Agency
FERC	U.S. Federal Energy Regulatory Commission
FTE	Full-Time Equivalent
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
GDP	Gross Domestic Production
GHGs	Greenhouse Gas Emissions
GSHP	Ground Source Heat Pumps
GWh	Gigawatt-hours
GW	Gigawatt
IRA	Inflation Reduction Act
ITC	Investment Tax Credit
kW	Kilowatt
kWh	Kilowatt-hours
MOCEJ	New York City Mayor's Office of Climate & Environmental Justice
MW	Megawatt
MWh	Megawatt-hours

NOAA	National Oceanic & Atmospheric Agency
NPCC	New York City Panel on Climate Change
NREL	National Renewable Energy Laboratory
NYISO	New York Independent System Operator
NYPA	New York Power Authority
NYSCAC	New York State Climate Action Council
NYSERDA	New York State Energy Research and Development Authority
O&M	Operations and Maintenance
OREC	Offshore Wind Renewable Energy Credits
OSW	Offshore Wind
RCP	Representative Concentration Pathways
REC	Renewable Energy Certificate
REOPT	Renewable Energy Integration & Optimization Tool
ROR	Rate of Return
SFHA	Special Flood Hazard Areas
Solar PV	Solar Photovoltaics
TOD	Time of Day
ULURP	Uniform Land Use Review Procedure
UNIPCC	United Nations' Intergovernmental Panel on Climate Change
VSC	Voltage Source Converter
WRRF	Wastewater Resource Recovery Facility

List of Definitions

Alternating Current (AC): An electrical current, the direction of which is reversed at regular intervals or "cycles."

Behind-the-Meter: Energy resources individual customers install on their own property to generate electricity to directly serve energy needs.

Combined Sewer Overflow (CSOs): When a mix of stormwater and untreated sewage discharges directly into the city's waterways.

Curtailment: When an electrical generation system (such as a solar array or offshore wind turbine) deliberately reduces its power output, often when there is insufficient electricity demand to absorb its generation.

Disadvantaged Communities (DACs): Energy customers that bear the burdens of negative public health effects, environmental pollution, impacts of climate change, and possess certain socioeconomic criteria, or comprise high-concentrations of low-and moderate-income households.

Direct Current (DC): An electrical current that flows in one direction.

Distribution: Transfer of electricity across shorter distances to end uses (i.e., utility customers) at a lower voltage compatible with a building's systems and equipment.

Distributed Generation: When a small-scale electrical generation system is connected directly to an electricity consumer, or to a distribution network rather than a transmission network. These small-scale generation systems are typically referred to as distributed energy resources, or DERs.

Emissions Factor: A representative value that relates the amount of a pollutant released into the atmosphere with the associated activity. Factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned).

Energy Arbitrage: Technique of charging a battery storage system at off-peak hours, when prices are lowest, for discharge at future peak times to avoid or reduce electricity consumption from the grid. This method enables customers to reduce bill impacts, while also alleviating pressure on the grid, improving system reliability.

Energy Capacity: Total possible discharge capability (in kilowatts or megawatts), or its maximum rate of discharge starting from a fully charged state.

Front-of-Meter: Generation that delivers generated electricity directly to the electric grid, not an individual customer's facility.

Large-scale or Commercial-scale Generation: When a large electrical generation system is connected to transmission infrastructure and must pass through a transmission substation and distribution infrastructure before it reaches an electricity consumer.

Power: Rate at which energy flows, units in this report are watts, kilowatts (kW), and megawatts (MW).

Reliability: The provision of an adequate supply of electricity to satisfy load.

Rate of Return (ROR): The net gain or loss of an investment over a specified period of time.

Transmission: Transfer of electricity across long distances to distributors (i.e., utilities) at a higher voltage.

Converter Station: An electrical station that converts current from AC to DC electricity, or DC to AC electricity. Converter substations can also perform the functions of transmission substations.

Transmission Substation: An electrical substation that provides an entry point to the grid for AC generation, interconnects two different AC segments of the transmission system, or changes the voltage of AC electricity.

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