Ravenswood Generating Station, on the East River waterfront, is the largest power plant in New York City.

Credit: Lawrence Chernin

Utilities

A steam vent in Midtown

Credit: Jorge Royan

At night, the city is aglow: Times Square dazzles visitors with all shades of neon; lights trace the spans of bridges from the Verrazano to the Whitestone; and street lights illuminate the clouds of steam that rise from the streets of Manhattan. Energy—electricity, natural gas, and steam—makes so much that is iconic about New York City possible. Utility networks not only bring the city's famous skyline to life, they also run the subways, keep the city cool in summer and warm in winter, and support every aspect of the economy.

Under the surface of the streets and out of sight, layers of critical energy infrastructure power the city. Pipelines bring natural gas from across the country. Power lines link the city to the larger regional grid. Generators burn gas to produce electricity. Steam travels from large boiler and cogeneration facilities to buildings through miles of underground conduits. These systems are complex and, in many cases, old—yet most New Yorkers do not think about them until they fail. However, these critical systems deserve careful consideration because they are vulnerable to extreme weather events—and likely will become more vulnerable as the climate changes.

Extreme weather has always been an issue for utility networks, including in the last decade. In 2006, a heat wave caused an extended blackout that affected approximately 250,000 Queens residents. In 2011, Hurricane Irene's floodwaters came close to leaving parts of Lower Manhattan in the dark. And in the summer of the same year, another heat wave led to an all-time record for city electricity demand.

But Sandy was different. Never before had the city experienced a weather event on this scale (the citywide blackout in the summer of 2003 was a result of a software error several states away). During and after the storm, one-third of the city's electric generating capacity was temporarily lost. Five major electric transmission substations in the city flooded and shut down. Parts of the natural gas distribution network were inundated. And four of six steam plants in the city were knocked out of service.

By the time the storm passed, more than 800,000 customers (representing over 2 million New Yorkers) were without power and 80,000 customers were without natural gas service. A third of the buildings served by the city's steam system—including several major hospitals—were without heat and hot water.

Within a few days of Sandy's departure from New York, much of the city had regained service. In some neighborhoods, however, including large parts of the Rockaways and Staten Island, outages lasted for weeks, as crews of electricians and plumbers went door-to-door to repair flooded equipment.

As serious as the damage to the city's energy infrastructure was, in many ways, the impact that this damage had on people and businesses was even worse. Hospitals had to be evacuated under emergency conditions when primary power was lost and backup generators failed. In high-rise buildings, elevators did not run and most taps above the seventh floor went dry because water pumps had no power. Many offices were left in the dark and without heat. The power outage caused transit shutdowns that prevented employees from going to work, even if their offices were unaffected. The real cost of the hurricane was measured less in repairs to energy infrastructure than in the profound disruption to the existing patterns of city life and commerce.

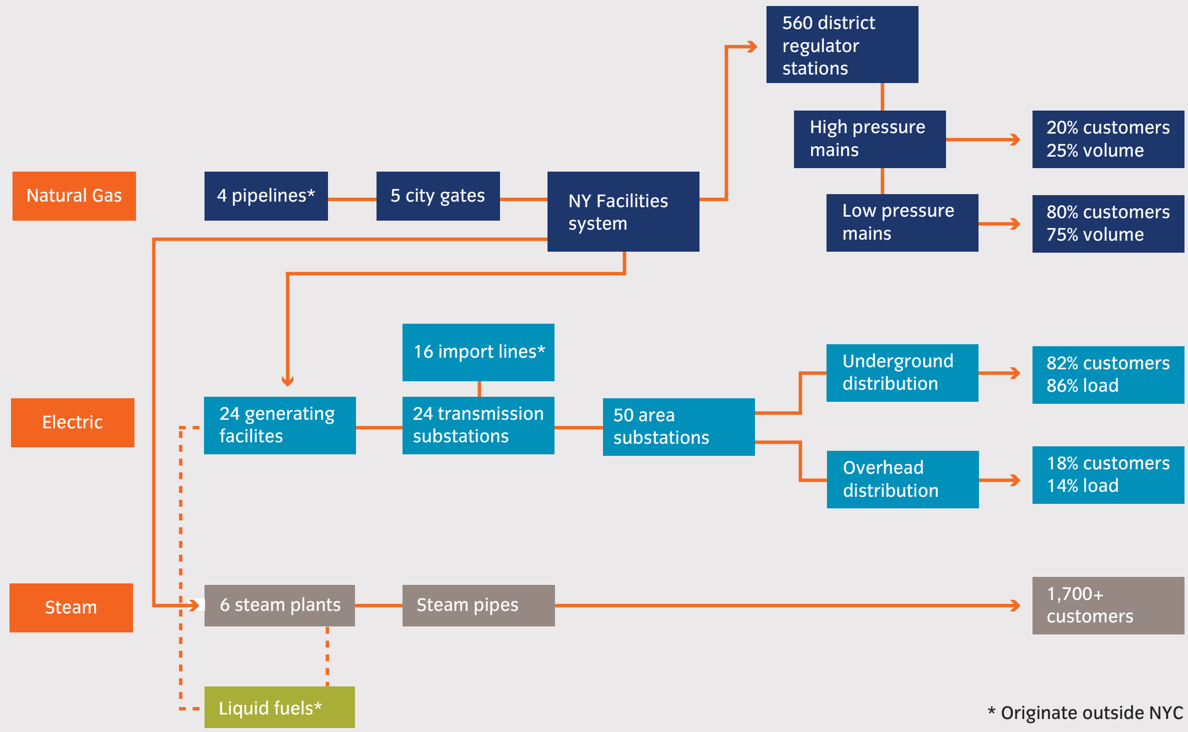
In the future, stronger storms and longer and more intense heat waves will likely pose new challenges to energy infrastructure. The city's energy systems—although reliable during ordinary weather events—need to be upgraded.

In keeping with the overarching goals of this report—which are to limit the impacts of climate change while enabling New York to bounce back quickly when impacts cannot be avoided—the City will work with utility companies and regulatory bodies to improve the current approach to utility regulation and investment. The City will advocate for incorporating risk-based preparation for low-probability but high-impact events, spending capital dollars to harden energy infrastructure and make utility systems more flexible, and diversifying energy sources. Collectively these strategies will reduce the frequency and severity of service disruptions, while allowing for more rapid restoration of service when these disruptions do occur.

How the System Works

New Yorkers spend roughly $19 billion per year on the energy to power, heat, and cool their city. The city's highly interdependent electricity, natural gas, and steam networks are among the oldest and most concentrated in the nation. Yet they are also still among its most reliable. These systems bring energy in bulk into the region and then transport it through layers of infrastructure, reducing levels of voltage (for power) or pressure (for gas) along the way and ultimately delivering energy to consumers. To understand how this system works as a whole, it is first necessary to understand its constituent parts. (*See graphic: Diagram of the Utility Systems*)

Diagram of the Utility Systems



Source: OLTPS

Electric System

The world's first centralized electric generation and distribution system was developed in New York City in the 1880s, by Thomas Edison. As of the writing of this report, New York's electricity system has since grown to serve 3 million customers—including 8.3 million people and 250,000 businesses —who consume roughly 1.4 percent of all electricity produced in the United States. In summer, the grid handles peak loads of over 11,000 megawatts (MW)—almost twice as much as the next largest city, Los Angeles.

The electric system consists of three major elements: generation, which produces electricity; the transmission system, which transports electricity at high voltages to large substations; and the distribution system, which carries electricity from large substations to smaller ones and ultimately to homes, businesses, and other customers. This system is owned, operated, and regulated by a wide array of private and public entities. *(See graphic: Overview of Electric Industry Participants)*

Generation

Multiple private companies and a public authority own and operate 24 plants within or directly connected to New York City (the "in-city fleet"). These plants can generate up to 9,600 MW of power, which is more than 80 percent of New York City's peak demand (defined as the peak level of electricity demand required on the most power-intensive days each year). Usually, only a subset of the in-city fleet will be running at any given time, with roughly 50 percent of the city's needs met with cheaper electricity imported from Upstate New York and New Jersey. The entire in-city fleet operates only during periods of peak electricity usage, such as during summer heat waves, when the use of air conditioning soars. New York City reached an historic peak of over 11,500 MW during a heat wave in July 2011, when temperatures reached over 100 degrees Fahrenheit for three consecutive days.

The in-city generation fleet is fueled predominantly by natural gas, with many plants also able to burn fuel oil. All of the in-city plants are located along the waterfront, with more than half concentrated in Astoria and Long Island City in Queens. Almost two-thirds of the fleet is more than 40 years old, equipped with technology that has lower efficiency and higher air emissions than modern plants.

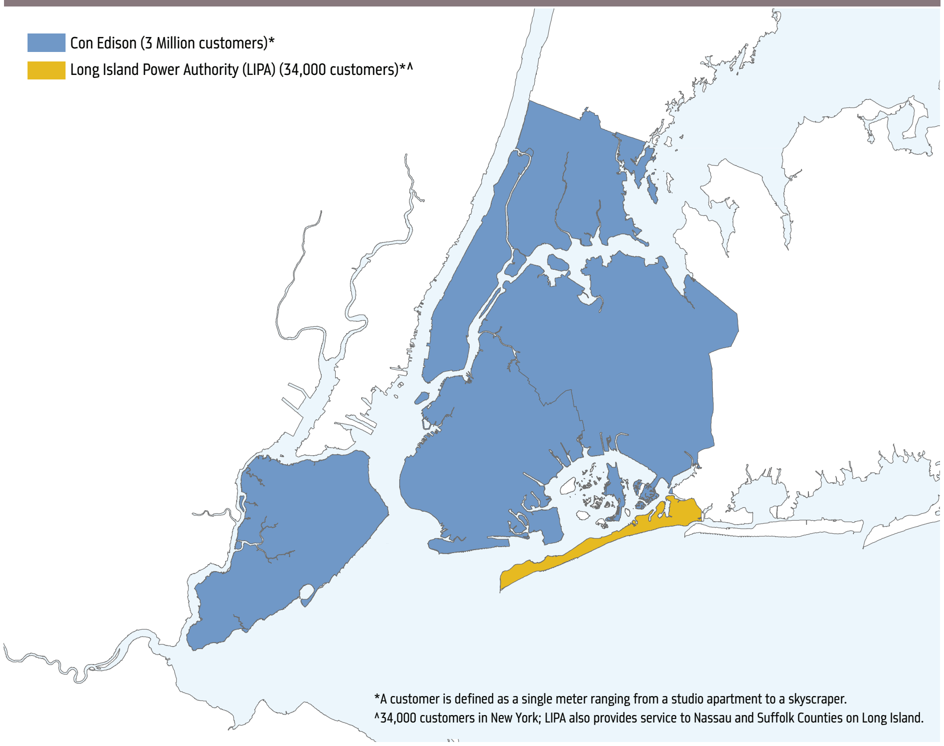
In addition to the in-city generating fleet, another small but growing source of energy in the New York market is customer-sited distributed generation (DG). Much of the 160 MW of DG capacity in New York consists of combined heat and power (CHP) installations, with smaller installations of renewable generation, including solar photovoltaic panels and fuel cells. CHP installations typically are found at large residential complexes, hospitals, and universities. These systems are usually in operation most of the time, replacing or supplementing electric power received from the grid. Some of these installations also are configured so they can operate independently of the grid during blackouts.

Transmission

Long-distance transmission lines connect the city with up to 6,000 MW of supply from areas as near as Northern New Jersey, Long Island, and the Hudson Valley, and as far as Northern and Western New York State. Both in-city-generated and imported electricity feed into Con Edison's electric grid at 24 high-voltage facilities housing switching and transformer equipment—known as transmission substations. Each of these substations routes the electricity that powers a large number of customers or clusters of critical infrastructure. In fact, a single substation in New York may support hundreds of thousands of customers—numbers that make New York's transmission system rare among other US systems.

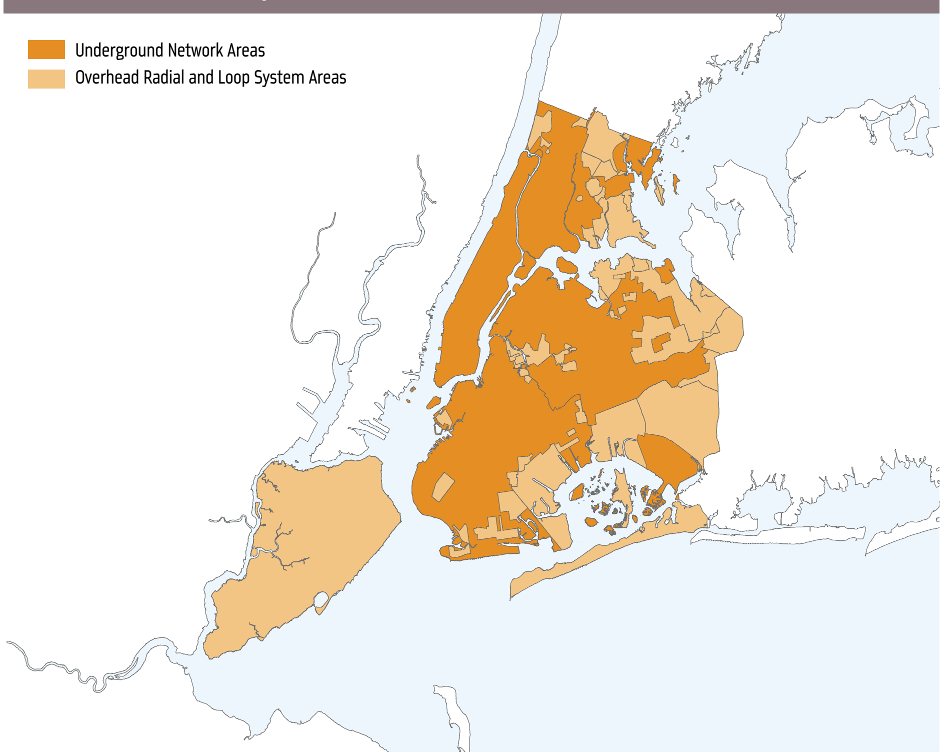
At the city's transmission substations, transformer equipment decreases electrical voltages. Electricity is then sent at these lower voltages through sub-transmission lines to area substations. There, smaller transformers decrease voltage once again and feed the

Electric Service Territories



Source: Con Edison, LIPA

Electric Distribution Systems



Source: Con Edison, LIPA

distribution system. The New York Independent System Operator (NYISO) coordinates the flow of electricity on the transmission system across the state, while Con Edison operates the transmission facilities it owns in the city.

Distribution

Con Edison is the primary electric utility in the city, providing electric distribution services to all five boroughs. The one exception is the Rockaways, which are served by the Long Island Power Authority (LIPA), a public authority controlled by New York State. LIPA does not operate and maintain its distribution system directly. Rather, it contracts for the operation and maintenance of this system to National Grid. This arrangement is set to expire at the end of 2013, when a subsidiary of Public Service Enterprise Group (PSEG) is scheduled to take over for National Grid for a 10-year period thereafter. (*See map: Electric Service Territories*)

The utilities' distribution systems consist of feeder lines that originate from "area substations," which are smaller than the transmission substations described above, but are nonetheless critical. Area substations typically serve one or two neighborhood-level "networks" or "load areas" of customer demand, each of which includes tens of thousands of customers.

In densely populated areas, such as Manhattan and certain portions of the other boroughs, the distribution system that carries power from area substations to end users consists of underground network systems—that is, systems that operate as a grid that can serve customers via multiple paths. In the rest of the city, the distribution system consists of a combination of underground and overhead loop systems and radial lines—that is, systems with simpler architecture, though also with fewer redundancies. These loop systems and radial lines account for about 14 percent of load on Con Edison's distribution system. LIPA's system in the Rockaways is made up exclusively of loop and radial systems. (*See map: Electric Distribution Systems*)

Customers ultimately receive electric power through service lines that are connected to their buildings' electrical equipment. In many cases, high-rise buildings or campus-style complexes have dedicated transformer equipment that serves these individual customers. This equipment is typically located in vaults beneath area sidewalks.

Natural Gas System

Natural gas fuels approximately 65 percent of heating and a significant percentage of cooking needs in buildings throughout New York. It also fuels more than 98 percent of in-city electricity production by power plants. A system of four privately-owned interstate pipelines transports natural gas from the Gulf Coast, Western Canada, and other production areas into the city at interconnection points called "city gates."

From the various city gates, high-pressure gas flows through an intra-city transmission system known as the New York Facilities. Gas that is destined for New York City's power plants generally is drawn at high pressure directly from the New York Facilities. To reach most other customers, gas is delivered through a set of regulator stations that reduce the pressure of the gas and send it into a vast network of underground distribution mains. In the city, these distribution mains come in two varieties: high-pressure and low-pressure. The low-pressure system is composed of cast iron and bare steel mains—outdated infrastructure that gradually is being replaced by the system's operators. This system is located mostly in the oldest parts of the city. Newer, high-pressure mains tend to be made of coated steel and plastic.

In New York City, Con Edison owns and operates the gas distribution system in Manhattan, the Bronx, and parts of Northern Queens. National Grid owns and operates the system in the rest of the city. (*See map: Natural Gas Service Territories*)

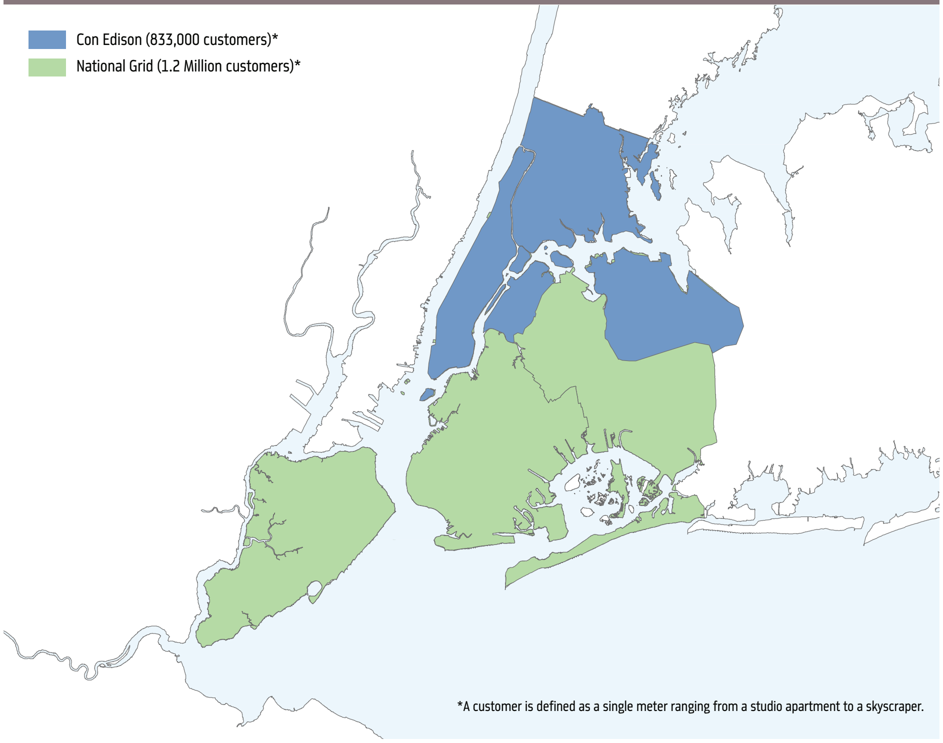
The city's natural gas demand usually peaks on cold winter days, when it can exceed the capacity of the four interstate pipeline connections. On those days, utilities ask electric generating plants and other large users to switch to liquid fuels. In the next three years, pipeline capacity will expand as private companies complete two new pipeline connections to serve the city, a significant advance in the City's cleaner burning fuels initiatives.

Steam System

The Con Edison steam system, one of the largest district steam systems in the world, provides over 1,700 buildings in Manhattan—including 10 hospitals and many of the city's largest institutions—with energy for heat, hot water, and, in some cases, air conditioning. The advantage of the steam system to customers is that it allows them to avoid owning and maintaining their own boiler systems. Instead, these customers are responsible for the easier task of maintaining on-site steam traps and condensate pumps. (*See map: Steam Service Territory*)

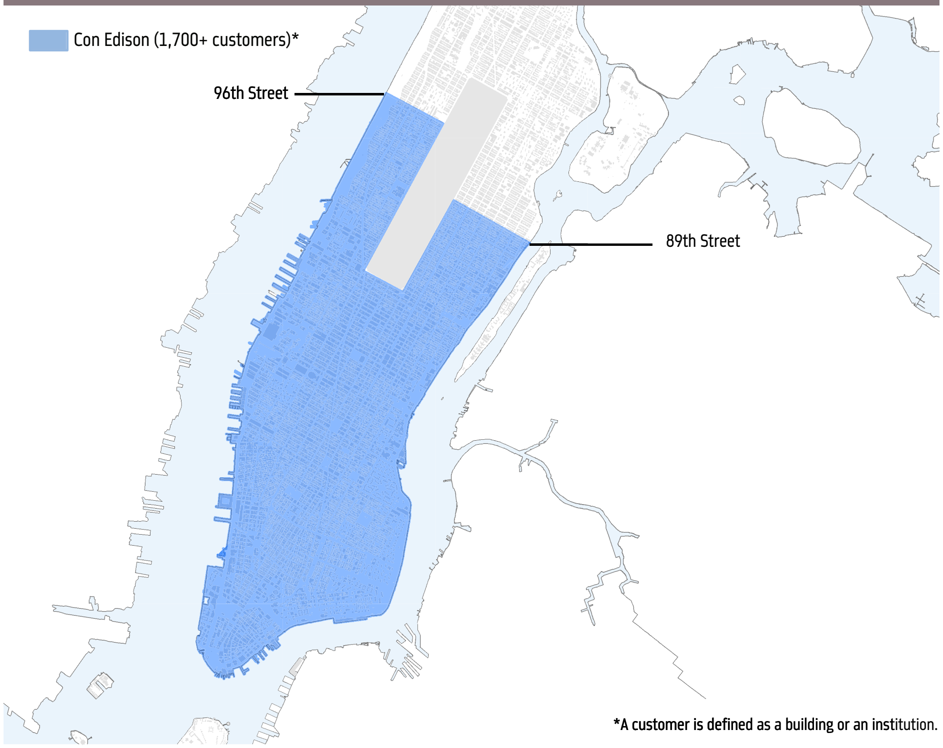
Six natural gas- and fuel oil-fired steam generating facilities in Manhattan, Brooklyn, and Queens can collectively produce over 10 million pounds of steam per hour, either cogenerating this steam along with electricity, or producing steam alone in massive boilers. A network of 105 miles of underground pipes transports this steam to customers.

Natural Gas Service Territories



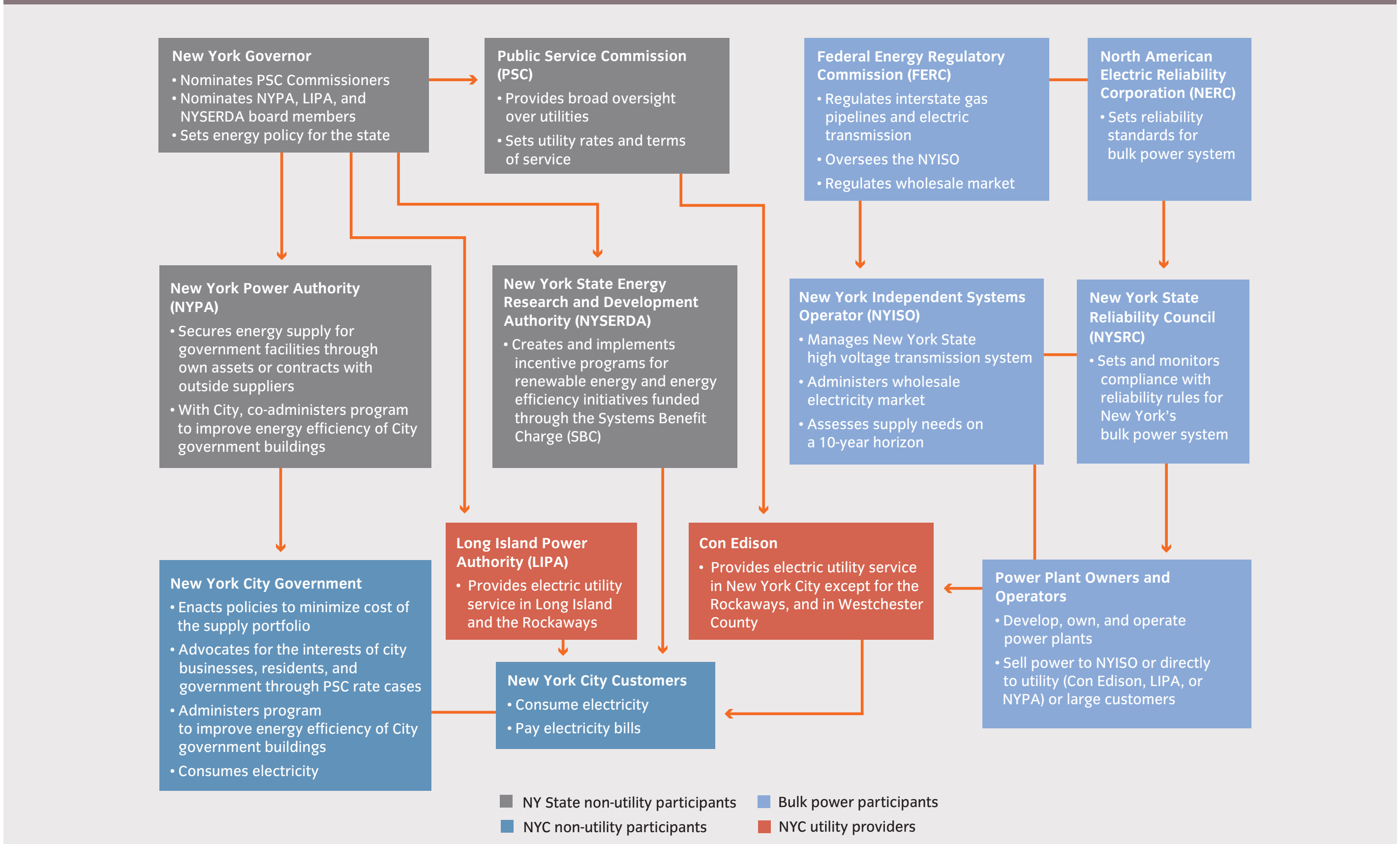
Source: Con Edison, National Grid

Steam Service Territory



Source: Con Edison

Overview of Electric Industry Participants



Source: OLTPS

Utility Regulation

A combination of private companies and public authorities own and operate New York's energy system, which is subject to a complex system of Federal and State oversight. Within this regulatory system, different entities are responsible for setting reliability expectations and standards, providing regulatory oversight, and for monitoring compliance with performance standards. The overall goal is to ensure safe, reliable, and affordable delivery of electricity, natural gas, and steam. (*See graphic: Utility Regulation*)

In the electric sector, the Federal Energy Regulatory Commission (FERC) oversees interstate transmission rates and wholesale electricity sales, while the New York State Reliability Council (NYSRC) establishes the State's electric reliability standards for the bulk power and bulk transmission systems. Subject to these standards, the NYISO operates the state's wholesale electricity market and high-voltage transmission system, and monitors the reliability of the state-wide transmission system. The New York State Public Service Commission (PSC) oversees all aspects of retail electric service, including the utilities' rates, terms, and conditions of service, as well as the safety, adequacy, and reliability of the service they provide.

Reliability expectations set by regulators govern the design and operation of the electric system. In the generation and transmission system, the reliability standards are set by the NYSRC, which requires that the bulk power and transmission system be designed so as to have an unplanned outage no more than once in 10 years.

Con Edison, in turn, designs and operates its electric system so that its network system, the portion of its system that serves the city's more densely-populated areas, is able to withstand the loss of two components within a distribution network and still maintain service. In less densely-populated areas, the system is designed to withstand the loss of one component.

Oversight of the rates, terms, and conditions of electric service is the domain of the PSC. One mechanism used by the PSC towards this end is the "rate case" process, in which the PSC determines the conditions for utility rate increases. During this process, a utility submits a filing that contains a justification for a rate increase, including details on capital investments that it proposes to make. The City and a variety of other stakeholders offer comments, testimony, and recommendations on the rate request and other related issues. The PSC then makes a decision about the proposed increase based on factors including whether the rates adopted will maintain safe and adequate service for customers. The same process applies to gas and steam utilities.

To measure how well the electric utilities are performing, the PSC uses quantitative metrics. The two main metrics are the System Average Interruption Frequency Index (SAIFI) and the Customer Average Interruption Duration Index (CAIDI). SAIFI measures the average number of interruptions per customer per year, while CAIDI measures the average length of each interruption. Con Edison's SAIFI is the lowest in the nation among large investor-owned utilities; its CAIDI, however, is above the national average. This generally reflects the fact that Con Edison's underground network systems are quite robust, suffering outages less frequently than typical above-ground systems – but when outages do occur, they can take longer to address and repair than overhead disruptions. (*See chart: Reliability Performance Comparison Among Selected US Utilities*)

For the natural gas and steam utilities, regulation of system design and operations is focused on safety. Oversight on rates and conditions of services is regulated similarly to the electric sector. In the case of the natural gas system, the FERC regulates interstate pipelines and the PSC

Utility Regulation

UTILITY SERVICE	RELIABILITY EXPECTATIONS	REGULATORY OVERSIGHT	PERFORMANCE MONITORING
Electric generation and transmission	• NYSRC requires that the probability of the loss of firm load due to system wide resource deficiencies be no more than 1 day per 10 years in accordance with Federal standards set by NERC	• FERC oversees NERC and NYISO, which manages bulk electricity generation and transmission in New York • NYSRC sets reliability standards (with FERC and PSC oversight)	• Compliance with NERC and NYSRC standards is monitored by the NYSRC and NYISO through reporting, audits, and investigations
Electric distribution	• Con Edison designs network system to withstand the loss of two components; parts of the overhead system are designed to withstand the loss of one component (depending on location and population density)	• PSC regulates rates, terms, and conditions of service	• PSC measures performance using SAIFI, CAIDI, and major outage events • PSC also tracks use of remote monitoring systems and restoration times following outages
Natural Gas transmission	• N/A, focus is on safety	• FERC regulates rates, terms, and conditions of service • USDOT regulates pipeline safety	• N/A
Natural Gas transmission	• N/A, focus is on safety	• PSC regulates rates, terms, and conditions of service • PSC regulates pipeline safety as USDOT's delegate	• PSC measures emergency response time to leaks, leak repair backlog, damages to gas facilities, and replacement of leak-prone gas mains
Steam	• N/A, focus is on safety	• PSC regulates rates, terms, and conditions of service	• PSC measures response time to leaks and leak repair backlog

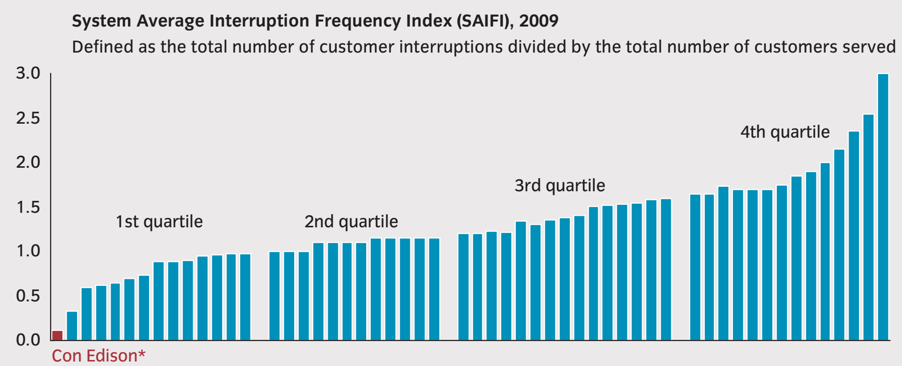
Source: OLTPS

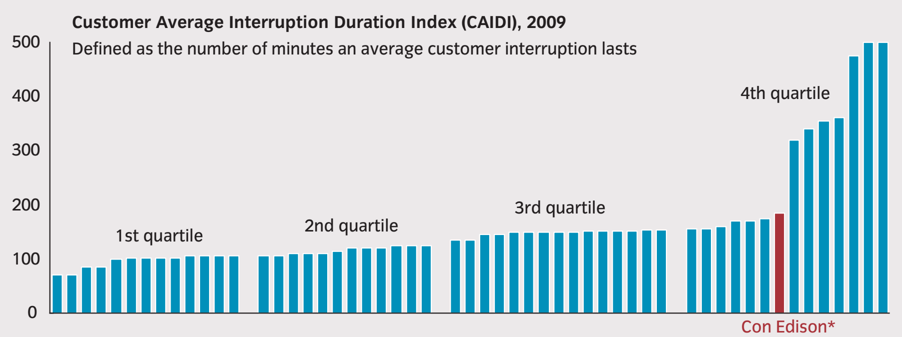
regulates local distribution companies and the provision of retail gas service. Gas pipeline safety is regulated by the United States Department of Transportation (US DOT), though in New York State, the PSC is the US DOT's designee for this purpose. The steam system, on the other hand, is regulated solely by the PSC. For both systems, performance metrics used by the PSC measure how well utilities manage leaks and how quickly they respond to reports of them (and, in the case of the natural gas utilities, odors).

Across all of the city's energy systems, the PSC also establishes financial incentives for each utility. These incentives impose revenue adjustments for failure to achieve specified thresholds or target levels of performance.

Climate change and its associated risks are not considered with respect to virtually any aspect of the regulatory framework applicable to New York's energy system. For example, the models that the NYISO runs to test whether the electric system will be able to meet future standards factor in the possibility of future heat waves, but do not yet consider the fact that in the future, heat waves are likely to be more frequent, more intense, and longer lasting than today, impacting electric demand. Similarly, when the utilities design their equipment, they tend to do so with a certain level of storm surge in mind. The regula-

Reliability Performance Comparison Among Selected US Utilities





* Con Edison numbers include the underground network system, which is unique among compared utilities
Note: Chart values include major storm events

Source: Edison Electric Institute, NYS PSC, Team Analysis

The Arverne Substation in the Rockaways was severely damaged by Sandy.

tors, however, do not yet require these utilities to consider a full range of present and future storm surge risks. When it comes to measuring performance, some versions SAIDI and CAIFI metrics that are used for the purpose actually exclude outages that are caused by major weather events.

What Happened During Sandy

Sandy caused unprecedented damage to New York's electricity and steam systems, while the city's gas system experienced damage that was smaller in scale and impact. In all three systems, however, damage occurred to infrastructure and customer equipment alike, leaving hundreds of thousands of customers without electricity, tens of thousands of customers without natural gas, and hundreds of the city's largest buildings without steam for heat and hot water.

Most of the city's energy systems ultimately recovered within a week of Sandy's departure. However, in parts of the city where floodwaters inundated basements and sub-basements, it took additional weeks to make the extensive repairs to homes and businesses that were necessary for utility service to be restored.

Electric System

The total number of New York customers left without power as a result of Sandy ultimately came to 800,000, which, given that utilities define a customer as a single electric meter, is equal to more than 2 million people. This is five times as high as the number that lost power during Hurricane Irene, the second most-disruptive storm in recent history. Despite actions by the utilities to protect their assets, the storm caused serious damage to generation, transmission, and distribution systems, as well as to customer-owned equipment. While utilities sought to restore services as quickly as possible, the extent of the damage led to a complex and lengthy restoration process. Service to most Con Edison customers was restored within four days. However, some customers' service was not restored for almost two weeks, making this event the longest-duration outage in Con Edison's history. LIPA's electric service restoration in the Rockaways took an average of almost 14 days—with some customers enduring outages over a much longer period.

In the days leading up to Sandy, the utilities took preemptive actions to minimize potential downtime by protecting and preserving their infrastructure. For example, to mitigate the impact of a surge (which, based on the best available forecasts, would top 11 feet at the Battery in Manhattan), the utilities protected critical facilities with sandbags, plywood and other temporary barriers. Then, as the storm arrived on the night of October 29, Con Edison shut down three entire networks preemptively—its Bowling Green and Fulton networks in Lower Manhattan, and its Brighton Beach network in Brooklyn—to prevent catastrophic flood damage to several clusters of underground distribution equipment as well as to customer equipment. Elsewhere, Con Edison prepared to de-energize feeders when flooding appeared imminent at key underground transformer vaults. Because of the configuration of the network distribution system, many of these preemptive moves caused the loss of electricity not only to customers in areas that were anticipated to be in Sandy's inundation zones but also to many customers that were expected to be outside of those zones.

When the storm arrived, the surge exceeded projections, topping out not at 11 feet but at 14 feet (MLLW) at the Battery and overwhelming many pre-storm preparations. Flooding forced several power plants and several transmission lines that import electricity from New Jersey to shut down, leaving New York City more dependent on a subset of its in-city generation capacity and on the electricity supply from Upstate New York. Some facilities also were damaged severely by Sandy's surge. This was true, for example, at the Brooklyn Navy Yard Cogeneration plant and the Linden Cogeneration plant. Other facilities, meanwhile, were disconnected temporarily because of impacts to the transmission system. While the impacts to electricity supply were significant, Sandy, ultimately, did not have the impact it might have had, had the storm arrived during the summer. (*See sidebar: Summer Demand Scenario*)

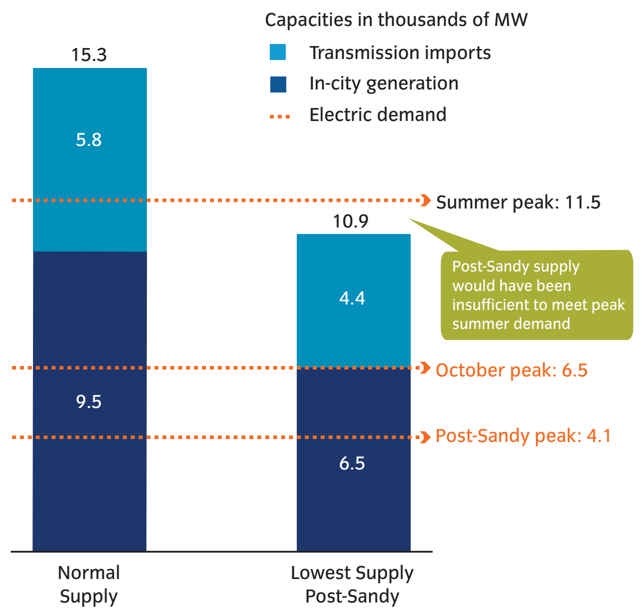
Perhaps the most significant (and dramatic) impact that Sandy had on the operation of the transmission and distribution systems occurred when the storm's surge came into contact with several key substations—including substations that, based on earlier surge forecasts, were not

Summer Demand Scenario

After Sandy, New Yorkers generally focused on the impact of the storm on the city's electricity consumers. By damaging distribution systems and customer equipment and disrupting activity across New York, the storm temporarily reduced demand for electricity in the city by some 40 percent. What has received less attention, however, is the fact that Sandy also disrupted a large number of in-city generators (directly and indirectly), leaving the city short of 3,000 MW of capacity upon which it normally could depend (almost one-third of normal in-city capacity). In addition, due to impacts to low-lying sections of the transmission infrastructure between New York and New Jersey, Sandy also left the city temporarily unable to access more than 1,400 MW of import capacity from New Jersey.

Because of the timing of Sandy's arrival in late October, when electricity usage tends to be relatively low, the remaining supply available to the city after Sandy ended up being sufficient to support the city's demand at the time. However, if Sandy had come during the peak summer demand period, it is possible that—once the storm had passed and peak load had recovered—the remaining in-city generation capacity would have been inadequate to meet the city's demand. This, in turn, could have resulted in severe outages on a much wider scale than those actually caused by Sandy. This disruptive outcome is one that the city may not avoid during future extreme weather events, particularly if hardening measures are implemented to protect distribution infrastructure and customer equipment without also protecting generating assets.

Electricity Supply and Demand Balance

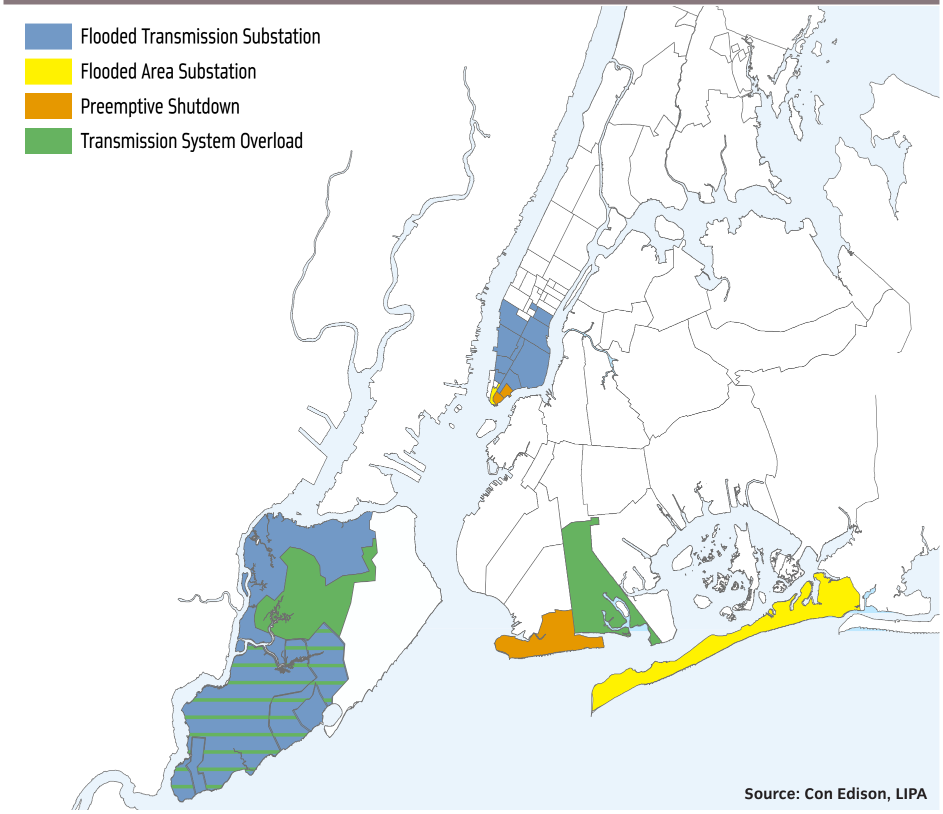


Source: NYISO

expected to be impacted. For example, in the Rockaways, all four LIPA substations were knocked out by floodwaters, resulting in widespread power failures throughout the peninsula. In Manhattan, Sandy's surge overtopped temporary protective barriers at Con Edison's East 13th Street complex, flooding two transmission substations and leading to an intense electric arc that could be seen from across the East River. Storm surge also impacted a Con Edison area substation in Lower Manhattan. Across these facilities, critical control equipment was submerged in saltwater. The damaged systems made the substations inoperable, knocking out power to most of Manhattan south of 34th Street (with one notable exception being Battery Park City, which is supplied with electricity from a transmission substation in Brooklyn). Finally, flooding of a transmission substation in Staten Island caused a grid-level shutdown in the western part of the borough.

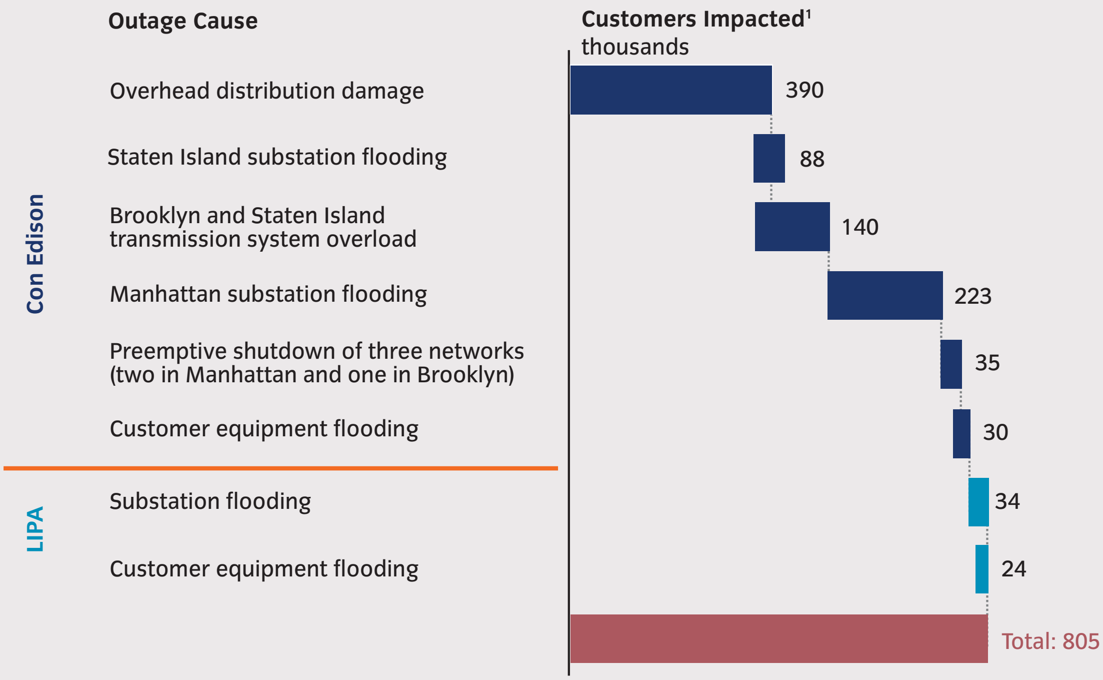
Each of these substation losses impacted tens or hundreds of thousands of customers. In all, approximately 370,000 electric customers in New York City lost power due to network shutdowns and substation flooding in Manhattan, Brooklyn, Queens, and Staten Island. (*See map: Electric Network Shutdowns During Sandy by Cause*)

Electric Network Shutdowns During Sandy by Cause



Source: Con Edison, LIPA

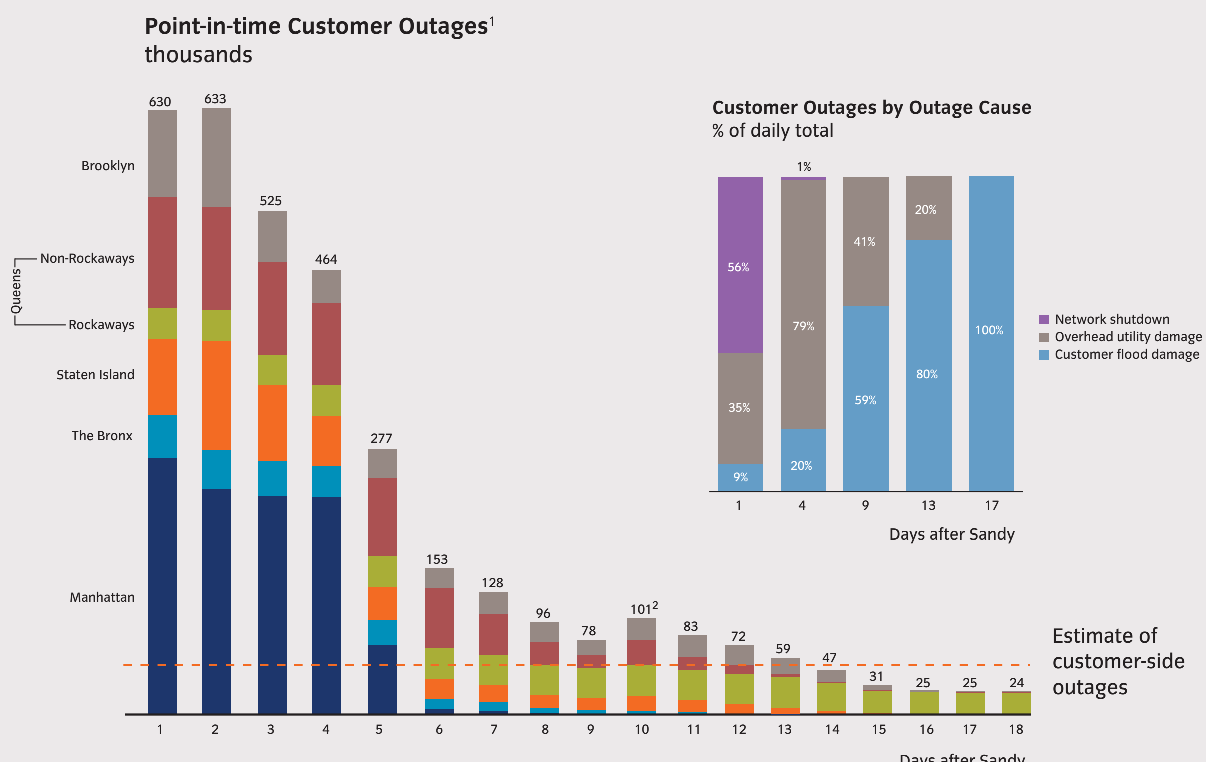
Causes of Electric System Outages and Customer Impacts



[1] Overlaps of customer counts exist between categories

Source: Con Edison, LIPA

Electrical Outage Restoration

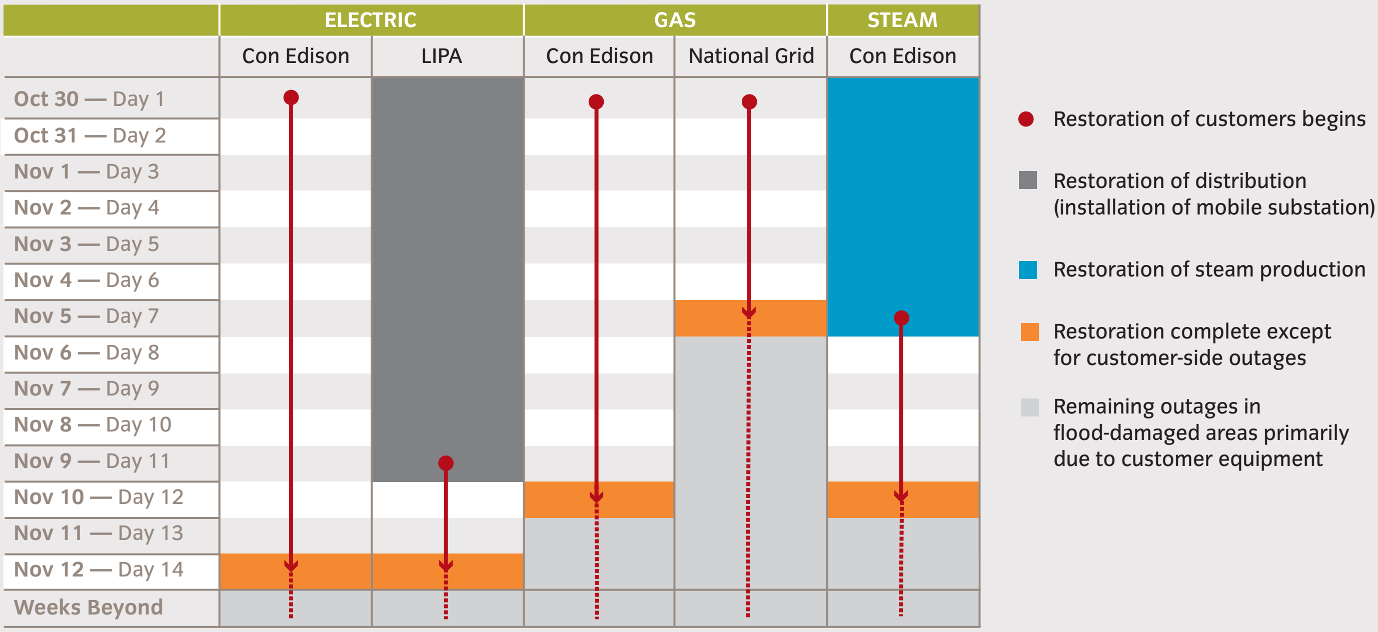


[1] A total of 805,000 customers lost power after the storm, but point-in-time daily estimates are lower because accounts went on and offline at different times

[2] Increase in customer outages due to the impact of nor'easter on Nov. 7

Source: Con Edison, LIPA

Electric, Gas, and Steam System Restoration Milestones



Source: Con Edison, LIPA, National Grid

Substation disruptions also led to stresses within the city's bulk transmission system, which became another cause of power outages. For example, a day after Sandy's departure, a transmission system overload resulted from flood impacts at two transmission substations in Brooklyn and Staten Island. The combination of these factors and the loss of all import capacity from New Jersey meant that the remaining transmission line capacity from northern parts of the city to parts of Brooklyn and Staten Island was inadequate to support the load. As a result, Con Edison was forced to terminate service to 140,000 customers, including some customers which had lost and regained power just the day before. This situation persisted for two and half hours, until additional generation (340MW from the Arthur Kill Generating Station that had been undergoing scheduled maintenance) could be brought online.

In addition to the outages caused by substation disruptions, Sandy caused localized outages in the city's overhead distribution system. Intense periods of sustained winds as well as wind gusts reaching 90 miles per hour toppled trees and pushed branches into power lines. Ultimately, 140 miles of overhead lines, 1,000 poles, and 900 transformers were damaged in Con Edison's system and had to be replaced or repaired. As a result approximately two-thirds of the city's customers served by the overhead system, or 390,000 customers, lost power at some point.

Within heavily flooded areas, approximately 55,000 customers primarily lost power not only because of damage to the utility system serving them but because of damage to electrical equipment in their buildings. In many cases, these customers suffered much longer outages due to the extensive repairs needed on their own equipment. Customers that were impacted by flooding in their basements included three hospitals. These hospitals eventually were forced to evacuate patients because they were unable to rely on their backup power systems. (*See chart: Causes of Electric System Outages and Customer Impacts*)

As Sandy's floodwaters receded, the utilities were faced with the massive task of restoring electricity to those who had lost it. The efforts to restore electric service were centered around repairs to damaged transmission infrastructure and local distribution system equipment. Of course, before restoration could occur, it was necessary for the utilities to determine where the need for restoration existed. The identification of system outages generally relies on a combination of grid monitoring technology, customer complaints, and, in areas of heavy damage, special assessment teams sent out by the utilities. Following Sandy, once the utilities assessed the location and extent of damage, restoration of service was prioritized to the extent possible for facilities necessary for critical care and public safety, City infrastructure, and individual customers. (*See charts: Electric Outage Restoration* and *Electric, Gas and Steam System Restoration Milestones*)

Electric service restoration to customers connected to the underground distribution system depended on the utilities' ability to reenergize inundated substations. In most cases, during Sandy, the major electricity-carrying equipment in these substations escaped catastrophic damage. In fact, most of the portions of the system that were damaged were restored in a matter of days. Once each substation was restored, service to the tens of thousands of customers could be turned on almost instantaneously.

Much work remained even after the restoration of substations. While Con Edison's decision to deenergize portions of the underground distribution system in Lower Manhattan and low-lying areas in Brooklyn and Queens preemptively reduced the extent of damage, localized areas of flooding required hundreds of underground vaults to be pumped dry. The combination of dewatering, the replacement of the many components that were damaged by inundation, and the inspections that were required prior to reenergizing turned out to be a significant undertaking for Con Edison.

Utilities from around the country sent "mutual assistance crews" to assist in this restoration effort. For example, Con Edison brought in nearly 3,400 overhead line workers (as well as over 400 underground workers) from as far away as California. As a result of these efforts, service to the majority of overhead and underground system customers was restored within a week. Due to the sheer volume of damage across the system, it took another week to restore power to all of Con Edison's customers who could accept it.

Utility workers pumping water out of underground electric vaults post-Sandy Credit: Con Edison

The situation in LIPA's territory in the Rockaways was worse. There, several substations were so badly damaged that a mobile substation unit had to be put in place while longer-term repairs were conducted. As a result, it took 11 days after Sandy passed before LIPA could begin to reenergize its grid. Three days later, LIPA was able to restore power to 10,000 customers, predominantly in portions of Far Rockaway, whose homes were built on higher ground. The majority of customers in Rockaway neighborhoods such as Belle Harbor, Rockaway Beach, and Arverne, had significant flood damage to electrical equipment in their homes and businesses, which further delayed service restorations.

As indicated, even when power was restored to different parts of the city's electrical grid, customers were not able necessarily to use that power in their homes and businesses; this was due, in many cases, to significant damage to customer-side equipment caused by the flooding. In these cases, the City worked with Con Edison, LIPA, and National Grid to create an innovative program for impacted homeowners called Rapid Repairs. This program, funded by FEMA, made licensed electricians available to repair customer-side electrical damage. By the time it ended, five months after Sandy, the Rapid Repairs program had helped restore service to some 20,000 homes.

It is worth noting that, amidst the widespread electric outages, there were some cases where facilities performed well on either backup generators or CHP systems. For example, at least five hospitals relied on backup generator systems in order to stay in operation during the storm and its aftermath. Meanwhile, New York University had success keeping key buildings on its Washington Square campus lit and heated thanks to a newly installed gas-fired CHP system, which it was able to operate seamlessly in isolation from the grid when the grid failed.

Natural Gas System

Overall, the city's natural gas system fared better than its electric grid. However, even this generally resilient system did not escape damage, with approximately 80,000 National Grid and 4,000 Con Edison customers ultimately losing service.

As was the case for the electric grid, Sandy's impact on the city's natural gas system began with a series of preemptive steps that were taken by Con Edison and National Grid. For example, as Sandy approached, the two utilities isolated some low-lying parts of their networks to ensure that any intrusion of water would be limited, rather than spreading system-wide. Both Con Edison and National Grid also shut down several regulator stations in anticipation of the storm.

As Sandy's surge peaked, Con Edison and National Grid needed to take immediate action, resulting in the shutdown of still more sections of their respective distribution systems. In some parts of the low-pressure distribution system, the pressure of floodwaters quickly exceeded the pressure inside the gas mains, resulting in water intrusion through cracks, holes and other weak points. Meanwhile, in the high-pressure distribution system, floodwaters entered some customer service lines. The net effect of the preemptive actions and the inundation damage was loss of gas service in a number of city neighborhoods, including Coney Island, Howard Beach, the Rockaways, Edgewater Park, Locust Point, City Island, and portions of the East Village and South Street Seaport. Additionally, some of Con Edison's gas control and monitoring equipment stopped functioning, due to the loss of power and telecommunications services.

As Sandy's floodwaters receded, restoration primarily depended on the removal of water from distribution mains, equipment and pipe inspections, and the re-lighting of customers' appliances. Though this work began almost immediately, damage to some system components was extensive. For example, in the weeks following the storm, National Grid had to rebuild 13 miles of gas mains serving Breezy Point (which had also been damaged by fire) and New Dorp.

Similar to the electric grid, restoration of the gas distribution system was still, in some cases, insufficient to re-light appliances in homes and businesses that were damaged by floodwaters. Here again, the City's Rapid Repairs program was instrumental in assisting homeowners with making repairs to damaged boilers and heating systems.

Steam System

During Sandy, one-third of the city's steam customers, including five acute care hospitals, experienced outages. As was the case for the electric grid and gas distribution system, Sandy's impact on the city's steam distribution system began with a series of preemptive steps that were taken by Con Edison. These included the closing of low-lying segments of the system, in order to avoid a damaging and potentially explosive effect called "water hammer" that occurs when cold floodwaters meet hot steam pipes. Con Edison also shut down two generating stations that were potentially vulnerable to inundation: East River and Brooklyn Navy Yard.

The storm surge from Sandy forced Con Edison to shut down two more generating stations, one at 59th Street and one at 74th Street in Manhattan. In total, during Sandy, the city's steam system lost nearly 90 percent of its generating capacity, resulting in a complete shutdown of the system below 14th Street. Other customers lost steam service when parts of the First Avenue distribution tunnel, which steam mains, gas mains, and electric lines traverse, were flooded with 500,000 gallons of water. Moreover, some customers' steam services were shut down when the electric grid failed in Southern Manhattan, and they were unable to power their buildings' systems.

Following Sandy, restoration of the steam system took approximately 12 days. This was not only because of the significant damage that had occurred but also because of the careful timing and sequencing required for restoration, including the repair of production capacity and dewatering of pipes, which are both necessary preconditions for the warming and pressurization of mains.

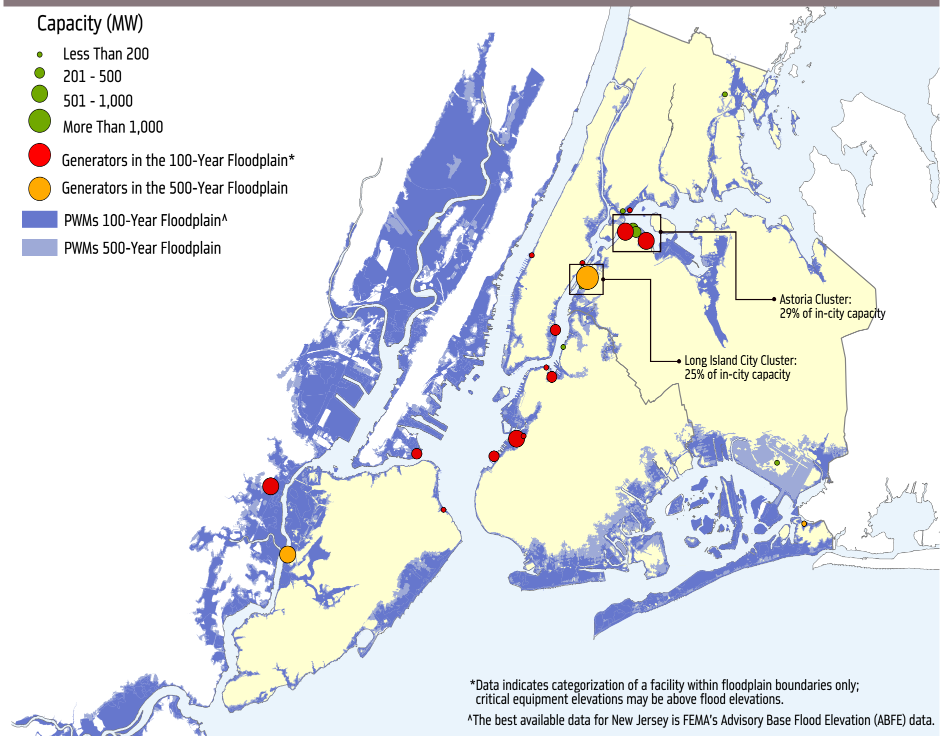
What Could Happen in the Future

Going forward, impacts from several types of extreme weather events could cause major failures in the city's utility systems, which could take multiple days to weeks to repair. The electric and steam systems face the greatest risks, with storm surge, paired with sea level rise, representing the most significant challenge. The electric system also could be impacted seriously by more frequent, longer, and intense heat waves. The natural gas system is fairly resilient overall, but storm surge could still pose a localized risk.

Major Risks

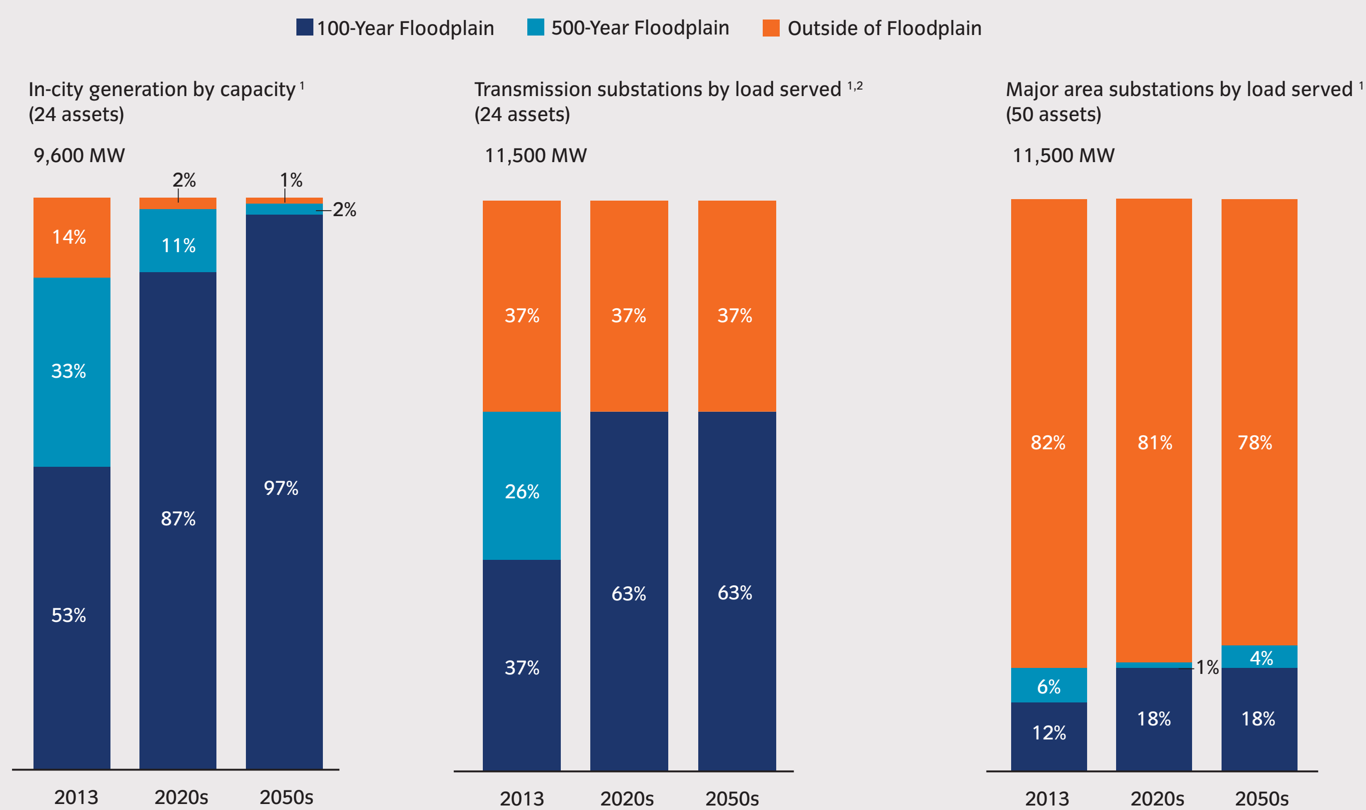
As Sandy demonstrated, storm surge could cause major loss of electric and steam service. The city's underground electric and steam distribution systems are vulnerable to floodwaters, as are electric and steam generating facilities. Today, 88 percent of the city's steam generating capacity already lies within the 100-year floodplain. In the electric system, 53 percent of in-city electric generation capacity, 37 percent of transmission substation capacity, and 12 percent of large distribution substation capacity lie

In-City Electric Generating Facilities in the Floodplain



Source: FEMA, OLTPS

Electric Assets in Current and Future Floodplains



[1] Data indicates categorization of a facility within floodplain boundaries only; critical equipment elevations may be above flood elevations

[2] Does not include transmission substations that do not serve load directly

Source: FEMA, CUNY Institute for Sustainable Cities, OLTPS

Risk Assessment: Impact of Climate Change on Utilities—Electric System

Major Risk Moderate Risk Minor Risk

	Scale of Impact			
Hazard	Today	2020s	2050s	Comments
Gradual				
Sea level rise				Minimal impact
Increased precipitation				Minimal impact
Higher average temperature				Minimal impact
Extreme Events				
Storm surge				Much of the critical infrastructure is in floodplains; flood risks will become worse over time
Heavy downpour				Minimal impact
Heat wave				Increased risk of outages due to the impact of heat waves on peak demand and on electric infrastructure
High winds				Risk of damage to overhead power lines

Risk Assessment: Impact of Climate Change on Utilities—Natural Gas System

Major Risk Moderate Risk Minor Risk

	Scale of Impact			
Hazard	Today	2020s	2050s	Comments
Gradual				
Sea level rise				Minimal impact
Increased precipitation				Minimal impact
Higher average temperature				Minimal impact
Extreme Events				
Storm surge				City gates could lose monitoring/control systems; low-pressure distribution pipes could experience water infiltration
Heavy downpour				Minimal impact
Heat wave				Minimal impact
High winds				Minimal impact

Risk Assessment: Impact of Climate Change on Utilities—Steam System

Major Risk   Moderate Risk   Minor Risk

	Scale of Impact			
Hazard	Today	2020s	2050s	Comments
Gradual				
Sea level rise				Minimal impact
Increased precipitation				Minimal impact
Higher average temperature				Minimal impact
Extreme Events				
Storm surge				Most steam generation assets and parts of the distribution system are in floodplains; flood risks will become worse over time
Heavy downpour				Localized outages are possible
Heat wave				Minimal impact
High winds				Minimal impact

within the 100-year floodplain. Based on the best available sea level rise projections, these figures are forecast to grow by the 2050s to 97 percent, 63 percent, and 18 percent, respectively. *(See map: In-City Electric Generating Facilities in the Floodplain; see chart: Electric Assets in Current and Future Floodplains)*

For the natural gas system, the biggest risk that storm surge poses (both today and in the future) is to the distribution infrastructure. Although flooding in and of itself usually will not stop the flow of gas, if water enters pipes, service can be compromised. The low pressure system is particularly vulnerable to this type of infiltration. Further upstream, the risks are lower, since gas can continue to flow if water inundates a city gate or regulator station (though controls and metering equipment are not always impervious to flooding).

Another significant risk to the city's energy systems—primarily its electric grid—comes from heat waves. Historically, heat waves impacted the city's electric grid more frequently and more significantly than any other type of weather event. For example, in 2006 a heat wave-related electrical outage in Long Island City, Queens resulted in the loss of power to approximately 115,000 customers (or 25,000 residents)—some for more than a week. In the future, New York is likely to face longer, more frequent, and more intense heat waves.

Heat waves create issues for the electric grid in two ways. First, they typically lead to a significant increase in demand as the use of air conditioning soars. This risks an imbalance between demand and supply, which can lead to outages. Second, the very temperatures that cause increases in demand simultaneously strain the electric generating and distribution equipment itself. For example, a prolonged heat wave makes it difficult for electricity-carrying equipment (such as transformers) to dissipate heat, while urban heat island effects (where heat absorbed during the day is retained near asphalt surfaces) put particular strain on distribution equipment located underground. These factors can lead to equipment failures and cascading disturbances in the electric system.

These two risks caused by heat waves can be mitigated, to an extent, if the NYISO or utilities ask certain customers to reduce electricity usage (and pay them for doing so) as part of demand response programs. Additionally, utilities can implement network-wide voltage reductions (between 5 and 8 percent) to relieve stress on equipment in strained networks. Con Edison employed this strategy in the summer of 2012, reducing voltage in 28 networks for a half day to 3 days at a time. However, if these measures do not sufficiently reduce demand and equipment stress, more significant impacts could occur, including the disconnection of entire neighborhoods or—when all strategies fail—cascading blackouts. *(See map: Heat Wave Impact: Voltage Reduction in Con Edison Networks)*

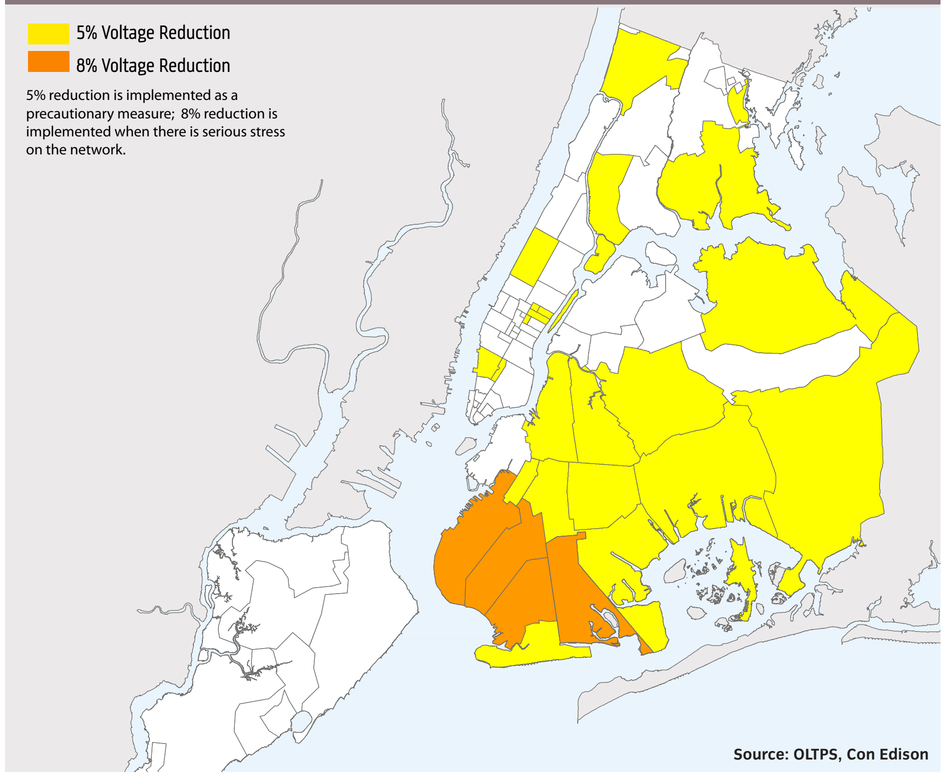
Finally, in addition to storm surge and heat waves, the vulnerabilities of the various energy systems present a significant risk to their sister systems, due to their interconnectivity. For example, natural gas and liquid fuels are necessary for the generation of much of the city's electricity and steam. Thus, disruptions to the fuel supply chain may in turn disrupt power and steam production. The steam system is also vulnerable to large-scale power outages: All of the city's steam generating plants rely on electric equipment, and although backup generation is often available, switching to it requires time, meaning that the steam system is vulnerable to depressurization during the downtime. This is what happened during the citywide power outage of 2003, when the entire steam system was shut down for more than five days.

Other Risks

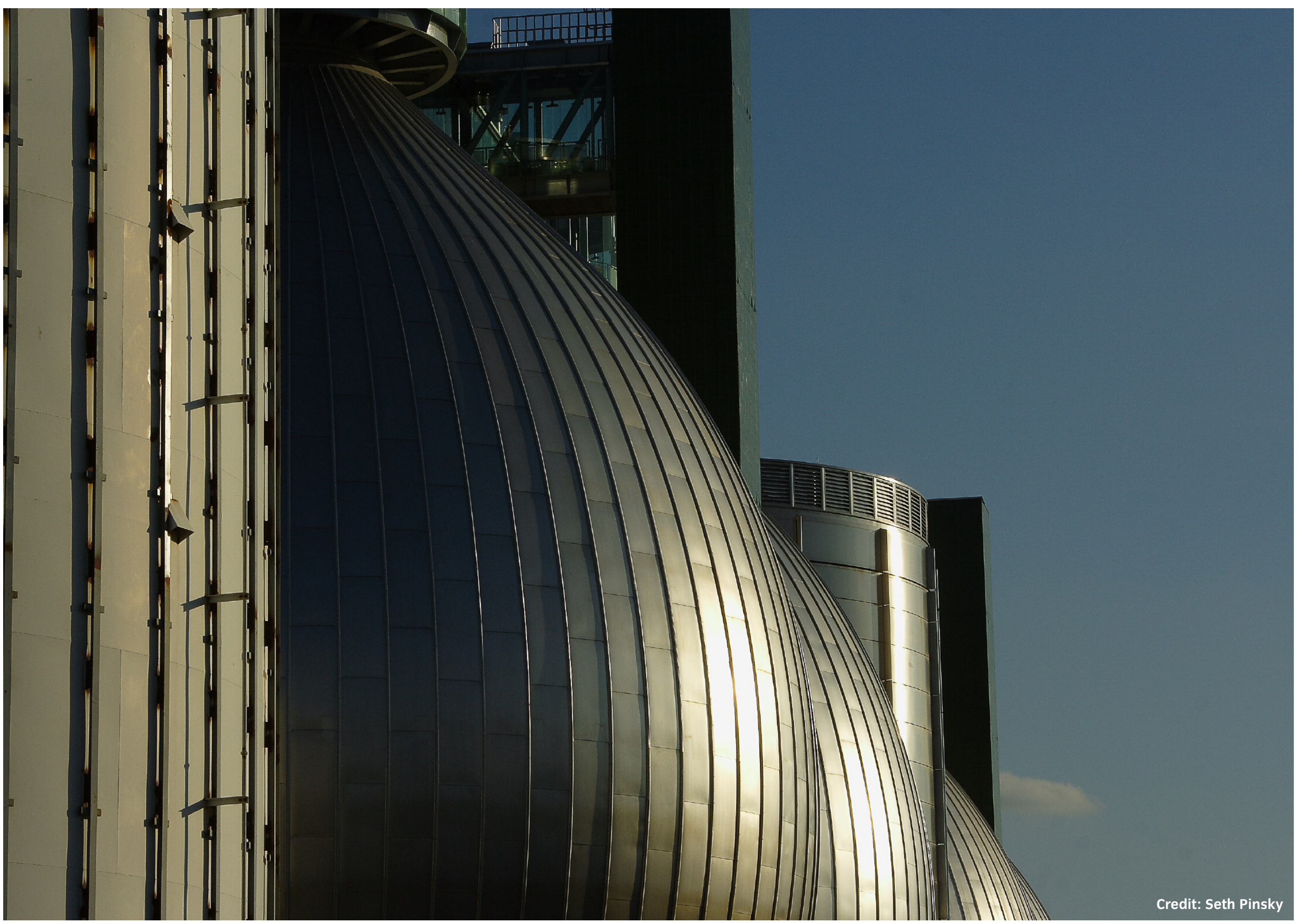
High winds will continue to pose a serious risk to the electric system looking forward. Since most wind-related damage occurs when winds topple trees and branches into power lines, the damage tends to cause more localized outages, rather than system-wide issues. That said, hurricanes and other large storms with significant wind can lead to damage that is more widespread.

Meanwhile, for the steam system, tropical storms or hurricanes that bring heavy downpours may present some of the same challenges that surge does, though likely on a much more localized basis. Large volumes of water around steam mains prevent condensate traps from functioning properly, potentially leaving piping vulnerable to water hammer effects that can shut down steam mains.

Heat Wave Impact: Voltage Reduction in Con Edison Networks



Source: OLTPS, Con Edison



Credit: Seth Pinsky

This chapter contains a series of initiatives that are designed to mitigate the impacts of climate change on New York's utility systems. In many cases, these initiatives are ready to proceed and have identified funding sources assigned to cover their costs. With respect to these initiatives, the City intends to proceed with them as quickly as practicable.

Certain other initiatives described in this chapter may be ready to proceed, but still do not have specific sources of funding assigned to them. In Chapter 19 (*Funding*), the City describes additional funding sources, which, if secured, would be sufficient to fund the full first phase of projects and programs described in this document over a 10-year period. The City will work aggressively on securing this funding and any necessary third-party approvals required in connection therewith (i.e., from the Federal or State governments). However, until such time as these sources are secured, the City will proceed only with those initiatives for which it has adequate funding.

From the 19th century to today, New York's energy systems have evolved along with the city that they serve. However, emerging climate threats will necessitate a rethinking of important aspects of the systems' architectures. At the same time, new technologies present an opportunity to modernize these systems in ways that could increase their resiliency significantly.

To this end, the City will advance a series of proposals designed to enable electricity, gas, and steam to be delivered reliably to New Yorkers, even during the extreme weather events that are expected in the coming decades. These proposals will address gaps in the regulatory framework applicable to these systems, as well as the infrastructure that supports them. Collectively, even as the climate changes, these proposals will reduce the frequency and severity of service disruptions, while allowing for more rapid restoration of service when disruptions do occur.

Strategy: Redesign the regulatory framework to support resiliency

The first set of proposals is designed to address gaps in the regulatory framework that governs the city's energy systems. This will assist utilities and regulators with identifying and appropriately funding long-term capital projects that will make the electric, gas, and steam systems more resilient.

Initiative 1

Work with utilities and regulators to develop a cost-effective system upgrade plan to address climate risks

Utilities and regulators long have employed analytical techniques to ensure adequate energy supply in the event of heat waves or failure of individual pieces of equipment. However, regulators generally do not require utilities to prepare for the possibility of losing entire facilities to weather events such as storm surge, nor do they consider the indirect economic and societal impact of such events. This is primarily because current guidelines instruct utilities, in designing their systems, to consider what is known and measurable—an approach that does not address low-probability but high-impact events such as Sandy.

The City, through the Mayor's Office of Long-Term Planning and Sustainability (OLTPS), will work with utilities, regulators, and climate scientists to adjust the existing regulatory framework to address these shortcomings. These changes will seek to require utilities to analyze costs, benefits, and risks, and to upgrade their systems as appropriate to withstand the sorts of high-impact risks that they face not only today, but also are likely to face with increasing frequency in the future. At the same time, the City will seek modifications in the ratemaking process to ensure that resiliency-related investments are given due consideration and that the utilities have a reasonable opportunity to recover those investments, just as they now recover their investments related to reliability.

Underlying all decisions on infrastructure upgrades that address extreme weather and climate change resiliency (including the type of investments that the City will seek to encourage utilities to make through the aforementioned regulatory changes) is an accurate assessment of risks. This is because not all assets need to be protected to the same standard, given that some are more vulnerable or important than others. To avoid unnecessary rigidity, the City will advocate for the use of probabilistic risk assessments by regulators and utilities to help guide the most efficient use of the utilities' capital budgets.

OLTPS has taken the first steps towards developing a risk assessment model that takes into account storm probabilities and future surge heights, quantifying possible customer outages and economic losses, and thereby beginning to identify the system assets that should be prioritized for protection. OLTPS will work with the utilities and climate scientists to continue to refine this model, with the goal of building a cost-benefit tool upon which to base storm hardening investment decisions that the PSC could incorporate into its utility regulation framework. (*See sidebar: Climate Risk Model for the Electric Sector*)

Initiative 2

Work with utilities and regulators to reflect climate risks in system design and equipment standards

To date, the system planning approaches and design standards used by New York's utilities and regulators have ensured highly reliable systems in New York. However, they have not been established with the goal of optimizing system resiliency. Ultimately, the city's systems should be capable not only of reliable day-to-day operation, but also of remaining operational during extreme weather events (such as hurricanes, tropical storms, and heat waves), and recovering quickly when parts of the system fail.

This can be achieved in part by considering climate change impacts in system planning

Climate Risk Model for the Electric Sector

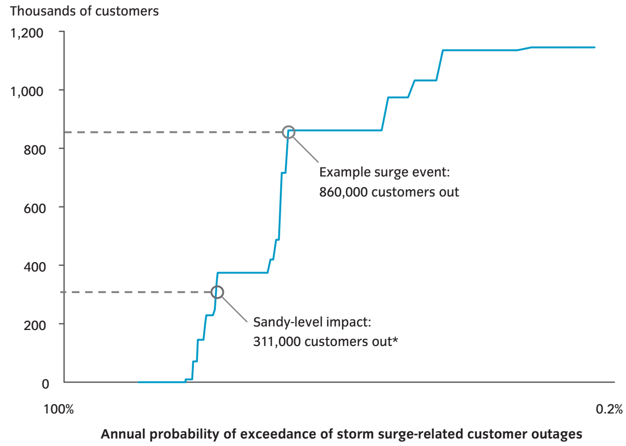
Extreme climate events may be difficult to predict more than a few days in advance—but their general patterns of occurrence are measurable. In the electric sector, these measurements can support analytical techniques that reveal the extent of existing and future risks and support better decision-making as utilities and regulators decide how much and how quickly to invest to prepare for heat waves, storm surges, and high wind events.

OLTPS, with support from the Analytics Division of the Mayor's Office of Policy and Strategic Planning, has taken the first steps towards a more quantitative approach to addressing the climate-related risks to New York City's electric systems. The Electric Sector Storm Surge Risk Model (ESRM), which the City is developing, contains three main modules:

1. The storm surge module, which builds on third-party storm models and climate change projections from the NPCC to generate hundreds of inundation scenarios and associated probabilities of occurrence for critical electric infrastructure locations, looking at 2013, the 2020s, and the 2050s;
2. The network structure module, which maps out the dependencies between individual substations and the networks they serve and compares the design elevation of each substation with the surge height in each individual storm to determine whether or not it would remain functional; and
3. The customer module, which uses the wealth of data available to the City to move past the simple number of customers that a network serves towards a more nuanced understanding of the network's importance—including the critical customers that depend on it, the amount of economic activity it supports, and, for example, the number of high-rise housing units that it serves that contain vulnerable populations.

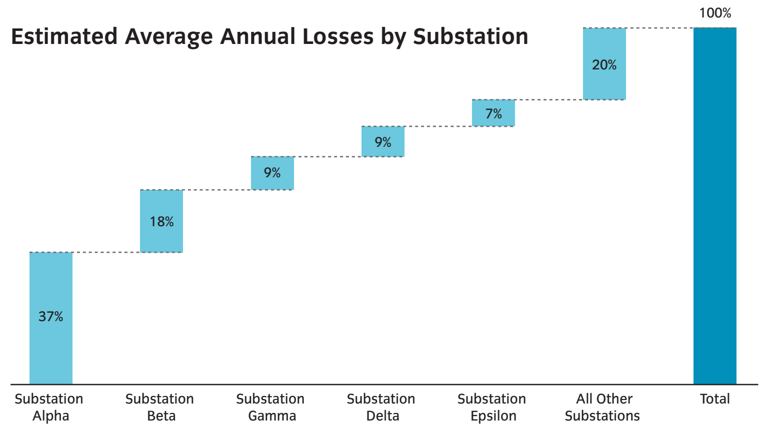
Customer Losses Due to Storm Surge-Related Substation Outages

A. Estimated Total Losses by Event Probability



*Outages associated with direct substation outage
Note: Preliminary analysis

B. Estimated Average Annual Losses by Substation



2013 climate risk
Note: Preliminary analysis

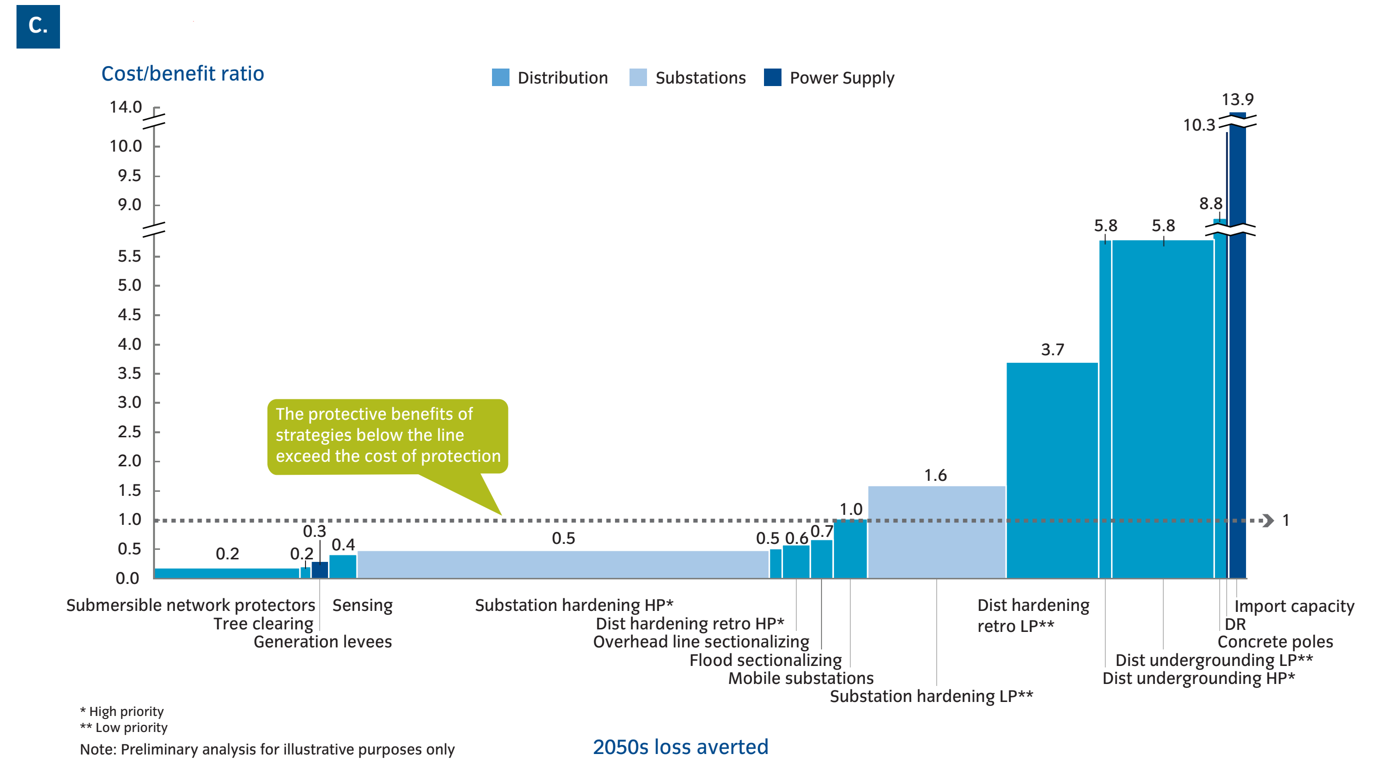
Source: OLTPS

The model is still in the early phases of development; the examples shown here illustrate how the three modules, taken together, make it possible to develop a preliminary quantitative baseline of risks that the electric system faces. For example, Chart A demonstrates the relationship between a given level of customer losses and the probability that this level will be met or exceeded in any one year. This analysis shows that, from this perspective, Sandy is not the "worst storm" that could hit the city. In fact, storms at the tail-end of the distribution, though unlikely, could result in customer losses almost four times as high as those suffered during Sandy. The model can also guide investment decisions. Again, by way of example, Chart B demonstrates that only five substations are likely to be responsible for 80 percent of annual expected customer losses. This would suggest that resiliency investments in these substations should be prioritized. If the outcomes are measured in terms of Gross City Product (GCP) losses resulting from outages, the order of priority among the five substations changes but the overall list remains the same.

The next step in the development of the model is to move beyond estimating baseline losses towards calculating the cost-effectiveness of various protection strategies and also guiding the standards to which critical assets should be protected. Further on, strategies to address heat and wind risks could be included as well, though the proper development of these elements would require a significant commitment of engineering resources. As an example, an early estimate developed as a proof of concept, shown in Chart C, suggests that hardening substations against surge may be a more effective use of funds than burying overhead power lines to protect them against wind.

The City has already been working closely with utilities and regulators to discuss these new quantitative approaches and to explore ways to incorporate them into utility decision-making and regulation—but much more work remains to be done. OLTPS will continue to refine the ESRM, and will work with utilities and regulators to expand the approach to include costs of protection strategies and to incorporate heat and wind risks within a common framework.

Estimated Risk Reduction Potential of Protection Strategies



* High priority
** Low priority
Note: Preliminary analysis for illustrative purposes only

Source: Team Analysis

Credit: Stefan Klaas

decisions. With regard to heat waves, for example, the City has worked with the New York City Panel on Climate Change (NPCC) and Con Edison to establish that an increase in average temperatures of just 1 degree Fahrenheit in New York in the years ahead could increase peak demand in the city by as much as 175 MW—a likely underestimate given that it does not include the impact of changes in average humidity (which could increase air conditioner use and therefore peak demand even further). The City's goal is for the NYISO to incorporate temperature and humidity forecasts into the Reliability Needs Assessment used in bulk power system planning. This would allow system planners to make adjustments to long-term plans for resource adequacy and transmission reliability to ensure supply will be adequate even as the climate changes.

Design of a more resilient system will also be accomplished in parallel by updating system and equipment design standards. The City, therefore, will call on utilities to work with it and the PSC to examine system designs and consider changes to design standards in light of the likelihood of higher ambient peak temperatures, longer heat waves, extended exposure to flooding and saltwater, and stronger and more sustained winds.

With regard to heat waves, a specific focus must be on Con Edison's underground networks. As part of this evaluation, the City will ask Con Edison and the PSC to reexamine and evaluate the strategy employed in recent years by which peak system demand during heat waves has been met by reducing voltage. In particular, the City will ask the utility and the regulator to assess the propriety of the use of voltage reductions in lieu of system reinforcements and upgrades, as well as the potential implications of relying on voltage reductions during more frequent and longer duration heat waves.

Initiative 3

Work with utilities and regulators to establish performance metrics for climate risk response

Regulators exclude performance during extreme weather events when evaluating utility performance and structuring the financial incentives associated with such evaluations. However, given the likely increases in frequency of these weather events, the time has come for utilities to be held accountable for their performance before, during and after such events.

The City will work with the utilities and the PSC to develop updated resiliency metrics and realistic performance standards, including appropriate incentives. Examples of performance metrics could include, among other things, minimum times to reach a 90 percent restoration threshold for customers following different classes of weather events. The City's expectation is that these metrics and standards would evolve over time as climate-related threats increase.

In connection with the metrics and standards above, the City also will call upon the PSC to require utilities to publish annual progress reports describing their preparedness for climate risks. Among the indicators described in the annual reports could be recent and projected climate-related capital investments, including replacements of unprotected conductors in overhead networks with extensive tree coverage, replacement of cast iron and bare steel gas mains in flood-prone areas, and installation of submersible underground equipment.

Strategy: Harden existing infrastructure to withstand climate events

Sandy demonstrated how the failure of key nodes in the energy distribution system can have widespread impacts on the city's energy systems, with significant repercussions for people, businesses, and communities. To address this, the City will call upon the utilities to identify high-priority infrastructure that is vulnerable to increasingly common climate risks, such as floods and heat waves, and to make the investments necessary to harden that infrastructure.

Initiative 4

Work with power suppliers and regulators to harden key power generators against flooding

As described above, 53 percent of New York City's power plants are in the 100-year floodplain. By the 2050s, 97 percent will be. Despite this, regulators do not yet require the owners of these plants to invest in flood-protection measures.

The City, working through OLTPS, will convene plant owners, utilities, and regulators to work together to prioritize, plan, and budget for the hardening of key in-city assets. For existing plants, the City will call upon the NYSRC to develop reliability rules that would be administered and enforced by the NYISO and that would require select plant owners to upgrade their facilities to withstand at least a so-called "100-year flood" (a flood level that has a 1 percent chance of being met or exceeded in any given year). The City will work with the facility owners, the NYSRC, NYISO, PSC, and Con Edison to identify the selected plants based on a cost-benefit analysis developed by all of the parties, and to determine the measures that should be undertaken, the timeframe for completing the measures, and a method by which the owners could recover the costs of such projects.

For new generating facilities and those undergoing substantial upgrades (such as repowering) that will be sited in the city's 500-year floodplain, the City further will call upon the PSC to require hardening to a 500-year flood elevation, or demonstration of other measures to be able to remain operational during, or recover quickly from, a 500-year flood event.

Initiative 5

Work with utilities and the PSC to harden key electric transmission and distribution infrastructure against flooding

Transmission substations, distribution substations, utility tunnels, and underground equipment are all at risk of flooding. For example, 37 percent of transmission substations are in the 100-year floodplain today and 63 percent are likely to be in the 100-year floodplain by the 2050s.

The City will work with utilities and regulators to protect these assets from future flood events. In the case of substations, the City, working with Con Edison, LIPA, and the PSC, will prioritize investments by evaluating the role that each such substation plays in system reliability, the number and criticality of customers that it serves (e.g., giving priority to hospitals), and the projected economic impact of its failure. The City's initial modeling suggests that 20 percent of transmission-level substations are responsible for 80 percent of annual expected customer losses.

Storm hardening measures to be implemented at the selected substations will be site-specific. In some cases, depending on the substation's configuration, selected assets within a substation could be elevated; in other cases, a combination of strategies, including protecting the perimeter of the facility, could be implemented.

In the case of utility tunnels, the City will support Con Edison's proposed plans to protect each from flooding. Finally, in the case of underground transformers and switches in the floodplains—of which 52 percent are currently submersible or water-resistant—the City will work with utilities and regulators to advance the goal of replacing, over time, all underground equipment in the 100-year floodplain with equipment that is submersible and unaffected by saltwater.

Initiative 6

Work with utilities and the PSC to harden vulnerable overhead lines against winds

During storms, high winds and downed trees threaten overhead electric poles, transformers, and cables. The City will work with Con Edison and LIPA to manage these risks through tree maintenance, line strengthening, and a line relocation program.

In some cases, rerouting lines underground may also be warranted, depending on the number of customers impacted and cost involved. In most cases, however, this option will be complicated and very expensive. On February 25, 2013, the City passed Local Law 13, directing OLTPS to conduct a study examining the "undergrounding" of overhead power lines in the city. Findings are to be submitted to the Mayor and City Council. The study is being conducted in partnership with Con Edison and will include an analysis of both projected costs and the expected effects on grid reliability of more extensive "undergrounding." It also will lay the foundations for including wind risks in the overall regulatory framework governing system reliability. If appropriate, the study will further identify the areas of the city, if any, where "undergrounding" could be of particular benefit, as well as those areas where it is viewed to be impracticable or subject to greater reliability risk.

Initiative 7

Work with utilities, regulators, and gas pipeline operators to harden the natural gas system against flooding

Although the city's gas system performed relatively well during Sandy, there were instances where remote operation of parts of the system failed. Additionally, the distribution system had localized outages due to water infiltration.

To ensure that future floods do not extensively compromise the gas system or reduce the ability of Con Edison or National Grid to control and monitor their systems, the City will work with the PSC, pipeline companies, and utilities to develop plans to harden all city-gates, interface regulator stations, and control equipment against flooding. To protect the distribution system, the City will work with the PSC, Con Edison, and National Grid to take steps to prevent water from infiltrating into gas pipes. In the low pressure system this will be achieved by expanding existing programs to replace the bare steel and cast iron pipes that are prone to corrosion, leaks, and cracks. In the high pressure system this will be achieved by installing backflow prevention devices on vent lines.

Initiative 8

Work with steam plant operators and the PSC to harden steam plants against flooding

Five out of six of the city's steam plants are in the floodplain today. Relocating these plants is neither practical nor cost-effective. The City, therefore, will call upon Con Edison and the PSC to increase the resiliency of these plants by taking flood-protection measures, including adding floodwalls, sealing building perimeters, raising equipment, and installing flood-protected, natural gas-fired back-up generators as appropriate (allowing Con Edison to deliver steam even during widespread power outages).

Strategy: Reconfigure utility networks to be redundant and resilient

Hardening existing infrastructure is only the first step in making the city's energy networks stronger. In the coming years, regulated utilities and private companies alike should rethink the entire architecture of their systems to help the City meet its twin goals of reducing the likelihood of failure and ensuring that service restoration can happen more quickly when failures do occur.

Initiative 9

Work with industry partners, New York State, and regulators to strengthen New York City's power supply

New York City's 9,600 MW of power generation can satisfy over 80 percent of peak demand, but the majority of these in-city power plants are located in the 100-year floodplain, all depend on natural gas and liquid fuel supplies (which themselves are subject to supply interruptions during extreme weather events), and almost two-thirds are more than 40 years old. The City will take steps to diversify and improve the sources of the city's power supply, and to do so in a way that will connect the city directly to new, low-carbon generation sources (which address some of the causes of climate change).

First, the City will continue to work with the NYISO to change wholesale energy rules to encourage generation owners to repower their older, less efficient, and higher polluting in-city power plants. The City already has facilitated the repowering of a 500 MW power plant operated by NYPA in Astoria.

Second, the City will encourage the development of new transmission lines connecting the city to other markets and sources of supply. The Hudson Transmission Project, which recently commenced operation, provides a new 660 MW connection between the city and the transmission system in the Mid-Atlantic and Midwestern regions. Additionally, the City actively supported the issuance of a State permit to construct and operate a 343-mile transmission line from Quebec that would allow for the importation of 1,000 MW of clean, low carbon Canadian hydropower directly to New York City.

Third, the City will continue to explore opportunities to expand low-carbon electricity generation sources in the area—working, for example, with NYPA and Con Edison on the potential development of up to 700 MW of offshore wind turbines in the waters south of the Rockaway peninsula. The Federal government currently is reviewing a NYPA lease application for use of underwater lands for such purposes.

Initiative 10

Require more in-city plants to be able to restart quickly in the event of blackout

Many New York City power plants, including some of the newest ones, cannot be restarted without external power sources (i.e., they cannot "black-start") after grid-scale outages. This slows the grid's ability to recover. State regulators only recently adopted a requirement that all new plants proposed to be built in New York either be able to provide for "black-start" capacity or to justify why such capacity is not included. This requirement did not exist when the city's newest plants received siting approval, while older in-city plants that do have such capacity are approaching the end of their useful lives. The City, through OLTPS, therefore, will work with generators, the PSC, the NYISO, FERC, and Con Edison to expand "black-start" capabilities within the existing generation fleet.

Initiative 11

Work with Con Edison and the PSC to develop a long-term resiliency plan for the electric distribution system

While hardening existing power assets is an important strategy, utilities also need to incorporate resilience into their long-term expansion plans, factoring in changing patterns of load growth. The City will call on Con Edison and the PSC to develop a long-term system resiliency strategy for the in-city electric system that will seek to divest load from coastal, "too-big-to-fail" nodes, with a strong bias towards building inland, so as to diversify geographic exposure. The strategy will also seek to relieve transmission limitations to large load pockets in Brooklyn and Manhattan.

Additionally, the strategy will provide for the system to evolve to contend with heavy blows from extreme weather events, such as storms and heat waves. Examples of potential projects that could emerge from the development of such a strategy could include: the creation of a new 345 kV link between Queens and the Bronx to strengthen the connection to Upstate electrical supplies and reduce reliance on the Astoria generation cluster; load divestment from substations to reduce congestion in the Brooklyn load pocket; and a new transmission corridor running inland between Staten Island and Queens. OLTPS will work with Con Edison, the NYISO, and the PSC to develop this strategy, outlining potential options, analyzing costs, and developing a roadmap for implementation.

Initiative 12
Work with utilities and regulators to minimize electric outages in areas not directly affected by climate impacts

Coastal flooding typically requires the shutdown of electrical feeders that could be exposed to floodwaters. In extremely dense areas of Lower Manhattan and Brooklyn, this can mean preemptive shutdowns of entire networks, with large swaths of customers losing service even if they are not directly affected by flooding.

To reduce the incidence of these so-called "sympathetic outages", the City will work with the utilities to design and implement new network boundaries. In the Fulton network, for example, a reconfiguration of the network would allow New York Downtown Hospital, which lies outside the 100-year floodplain, to continue to receive electricity during a coastal flood (rather than losing power as occurred during Sandy). Elsewhere in coastal areas served by the underground system, utilities should take measures like installing sectionalizing switches to allow more precise control over feeder shutdowns and isolations, reducing the number of customers impacted by a shutdown. Similar principles should be applied to the overhead system. For example, estimates by Con Edison indicate that 650 or more automatic reclosers or switches could be installed on overhead loop and radial systems citywide, each of which could locally have the effect of reducing by 50 percent the number of customers affected by a problem like tree branch damage to an overhead line. The City will work with Con Edison and LIPA to identify areas for priority attention.

Initiative 13
Work with utilities and regulators to implement smart grid technology to assess system conditions in real time

After an extreme weather event, the first task of any utility is to identify the location and extent of damage. Utilities usually rely on customer reports of power outages, together with on-site inspections by crews. Gathering information in this way, though, takes time and can be delayed by problems on the ground, such as impassable roads.

The City will call on Con Edison and LIPA to work with the New York State Smart Grid Consortium and stakeholders such as the USDOE to develop, demonstrate, and deploy low-cost sensor technologies, along with system integration, automated control, and decision-aided tools, that would allow the two utilities to assess system conditions in real time and facilitate timely dispatch of crews and equipment to the highest priority problem locations. To minimize costs, utilities could prioritize coverage of a statistically significant number of customers with smart meters, focusing, for example, on the 34,000 residential high-rise buildings in the city, or could prioritize coverage of key grid locations, such as at distribution sectionalizing switches, which could be monitored with advanced voltage sensors.

Initiative 14
Work with utilities and regulators to speed up service restoration for critical customers via system configuration

After extreme weather events, electric utilities may not be able to restore electric service to individual customers until damaged customer equipment is repaired or replaced.

The City, will work with Con Edison and LIPA to identify cost-effective ways to isolate critical customers, including through installing switches and other equipment along feeders that supply them. In some cases, this could allow utilities to restore service to these customers more quickly than they are able to restore service to others on the same circuit—or even to avoid service interruption in the first place. The City also will evaluate whether other options, such as on-site backup power for these critical customers, would be more cost-effective.

Initiative 15
Work with utilities and regulators to speed up service restoration via pre-connections for mobile substations

Mobile substation units can restore partial functionality of electrical distribution circuits while utilities undertake permanent repairs to damaged substations. This technology could potentially be effective at substations that support Con Edison's 4kV distribution grids or at LIPA's substations in the Rockaways. However, for these units to be effective, the utilities must pre-install the necessary connections in the system and have a way to source the mobile substations quickly.

The City will work with Con Edison, LIPA, and the PSC to complete technical evaluations of the use of mobile units as a strategy for high-priority substations, and, where this strategy is believed to be cost-effective, will advocate for its implementation. As part of this analysis, the City will work with the utilities to explore strategies for reducing the cost of these mobile units by, for example, sharing mobile units with neighboring regions.

Initiative 16
Work with pipeline operators to expand and diversify natural gas supply

The natural gas connections to New York City generally have sufficient capacity to provide the city's customers with gas, but on days when demand is high, all five city-gate connections are needed to prevent forced shutdowns.

The City will continue to support ongoing projects by gas pipeline operators to install additional city-gate capacity linking New York City to new natural gas pipelines. These projects include the Spectra pipeline, which will connect to Con Edison's gas system. The City supported the Federal approval of the Spectra pipeline and has continued to support its completion; it is now under construction. The City also has supported and will continue to support the issuance of a FERC permit for the Williams Rockaways Lateral, which will serve National Grid's gas network and is now seeking approval from regulators.

Initiative 17
Work with utilities and regulators to strengthen the in-city gas transmission and distribution system

Even when adequately supplied from the outside, New York's natural gas system has limited capacity to move gas within the city. If one city gate were to shut down on a high demand day, the

New York Facilities may be unable to supply the area that the city gate serves from elsewhere, which could cause significant outages. The City, working through OLTPS, will collaborate with pipeline companies, Con Edison, and National Grid to assess this risk and develop plans to strengthen the in-city transmission system.

Initiative 18

Launch energy infrastructure resiliency competition

Many resiliency solutions for the city's energy systems are available today, including building floodwalls or elevating equipment. However, new approaches—especially more cost-effective ones—could play a critical role in protecting these systems in the future.

To this end, the City will launch a Resiliency Technologies Competition that will allocate competitive grants to projects that use innovative technologies to further (1) building resiliency and (2) infrastructure resiliency. New York City Economic Development Corporation (NYCEDC) and the Mayor's Office will launch the competition in the summer of 2013 and expect to select winners in 2014. The City allocated $45 million in Federal CDBG funding to the competition.

Strategy: Reduce energy demand

In the years to come, rising temperatures will lead to higher peak demand. One strategy to accommodate it involves increasing the supply of energy available to the city. However, an equally (or more) effective—and far less expensive—strategy is to manage demand itself, both during peak periods, and more broadly. Programs are already in place to encourage both kinds of demand reduction. The City will continue to advance them, as well as develop new ones.

Initiative 19

Work with utilities and regulators to expand citywide demand response programs

In recent years, Con Edison and the NYISO have built up approximately 500 MW of demand response (DR) capacity to manage the brief periods of peak electrical demand that would otherwise require costly system expansions. The City will call on Con Edison, LIPA, PSC and the NYISO to increase this capacity and will support two strategies to accomplish this goal.

First, to create additional incentives for DR participation, the City will continue to support full implementation of a recent FERC ruling that brings DR pricing closer to the pricing of traditional generation. Second, to expand DR beyond its existing base of large customers, the City will work with the NYISO, Con Edison and LIPA to update participation standards and increase the role of private companies that aggregate DR potential across multiple small users.

City government also will play a role in decreasing in-city peak demand. It will do this directly, acting through the Department of Citywide Administrative Services (DCAS) to scale up its DR capacity with the goal of reaching 50 MW by 2018—including through expanding DR capacity at City facilities like wastewater treatment plants and City University of New York campuses.

Initiative 20

Work with government and private sector partners to expand the energy efficiency of buildings

Energy efficiency programs save owners money and reduce carbon emissions. These programs also have resiliency benefits, both because they reduce the chance of peak season outages by lowering demand and because they allow buildings themselves to remain habitable longer if outages do occur.

Expanding on the ambitious building energy efficiency programs put in place in PlaNYC in 2007, the City will scale up its energy efficiency efforts by focusing on energy use benchmarking, audit and retro-commissioning requirements, upgrades to lighting, and new financing approaches that would be available to a wider segment of New York City's one million buildings. In one example, the City will launch Green Light New York, a new energy efficiency and lighting center to educate designers, engineers, and the real estate community on effective technologies and best practices for lighting and building systems integration. In another example, the New York City Energy Efficiency Corporation (NYCEEC) will work with government partners including the New York State Energy Research and Development Authority (NYSERDA) and private lenders to identify and finance energy efficiency projects in the city.

Cost Impact and Recovery

Most of the initiatives described in this chapter carry a cost. Utility infrastructure costs of this type are typically included in the rates charged by utilities, subject to PSC authorization. Non-utility transmission providers and owners of electric generation facilities recover their infrastructure costs from the revenues they receive in the wholesale electric markets, and sometimes through rate surcharges authorized by the FERC.

Increases in infrastructure investments do not necessarily lead to higher rates because the utilities may be able to net the incremental costs against credits or savings produced from other program and project changes. Here, the City anticipates that most, if not all, of the infrastructure improvements related to the initiatives can be undertaken as part of the utilities' ongoing capital programs, thereby avoiding any rate increases. To the extent the resiliency investments are additive to rates, the increases are expected to be relatively small, perhaps no more than a fraction of one percent each year. While any increase in rates could have an impact on customers, businesses and residents expect and depend on reliable utility service, and the economic costs of utility outages can be enormous—a single day without electricity can mean more than $1 billion in lost economic output for New York City.


Worker repairing electrical infrastructure after Sandy

Credit: Con Edison

Strategy: Diversify customer options in case of utility outage

Even the most reliable utility networks occasionally will fail, and when they do, alternatives become important. Appropriately configured solar panels can provide electricity for individual customers and their local communities. Pre-installed connections to mobile boilers can expedite emergency provision of heat and hot water. CHP installations can supply all three. The City will explore both customer-level and district-wide options for power redundancy.

Initiative 21

Work with public and private partners to scale up distributed generation (DG) and micro-grids

There exists the potential for significant expansion of DG systems in New York. However, regulatory structures, financing challenges, and lack of information constrain further growth. The City, acting through OLTPS and the New York City Distributed Generation Collaborative (DG Collaborative)—a stakeholder group convened by the City in 2012, and consisting of utilities, regulators, the USDOE Northeast Clean Energy Application Center at Pace University, developers, and other industry representatives has been working to address barriers to DG and micro-grid penetration, with a goal of bringing citywide capacity to the original PlaNYC goal of 800 MW by 2030.

To promote DG, the City will work with the DG Collaborative to employ four main strategies. First, to address regulatory barriers, the City will call on the PSC to reevaluate the existing tariff structures and interconnection standards relating to DG in New York City. Second, to address the financing barriers to DG, the City will work with NYCEEC and New York State to increase access to low-cost financing for DG systems, and with NYSERDA to revise DG incentives, especially at critical facilities such as hospitals. Third, to address information barriers, the City will work with the DG Collaborative to provide technical assistance to property owners and developers, sharing best practices on DG projects and applying lessons learned from municipal buildings to privately-owned facilities. For example, the City has screened over 340 municipal buildings for technical compatibility with cogeneration, resulting in a 15 MW project under construction at Rikers Island and a 12 MW project at North River Waste Water Treatment Plant. The City will expand its screening analysis to include other DG technologies, such as fuel cells and renewables, working to expand DG in City buildings to 55 MW by 2017. Fourth, the DG Collaborative will work with City agencies to streamline administrative processes to promote prompt one-stop regulatory review of potential DG projects.

For solar photovoltaic systems (PV), in particular, the City will call on the Smart DG Hub—a stakeholder group convened by CUNY—to examine the applications of solar PV during outages and the technical and regulatory solutions for enabling cost effective and safe deployment of PV during outages.

Meanwhile, micro-grids, or neighborhood-scale networks of DG installations, have the potential to provide resiliency benefits, but require study. To encourage micro-grid adoption, the City will focus on four actions. First, the City will call on the PSC to clarify the rules governing the export of energy to multiple property owners and across roadways, so as to reduce uncertainty for private investors. Second, the City will evaluate the potential for a micro-grid pilot in clusters of City-owned buildings. Third, the City will work with USDOE, NYS Smart Grid Consortium, the DG Collaborative, and NYSERDA to examine the feasibility of micro-grid pilots throughout the city, including in areas like the Rockaways. Fourth, the City will work with NYSERDA and academic institutions to study the technical and economic effects of higher penetration of micro-grid systems on New York City's energy networks. Finally, utilities should incorporate micro-grid expansion into their planning.

Initiative 22

Incorporate resiliency into the design of City electric vehicle initiatives and pilot storage technologies

Electric vehicles (EVs) can emit 70 percent less carbon than average cars, one reason the City has one of the largest public sector EV fleets in the nation. With future enhancements, they also could have resiliency benefits. For example, during a power outage, an EV potentially could be used as an energy source to power a small home for a day.

The City, acting through OLTPS, will build on its work to accelerate EV adoption in the city, incorporating resiliency features into electric vehicle infrastructure. The biggest barrier to doing this is that the standards for two-way power flow between vehicles and chargers do not exist yet; even though the technologies have been tested in the US, national standards organizations have not yet codified the necessary protocols. The standards may not arrive for several years, but the City will work to ensure that the EV infrastructure being built today is sufficiently robust to accommodate two-way power flow in the future.

In addition, the City will pilot new battery storage applications and streamline regulation to enable private sector adoption. For example, NYCEDC is piloting a large battery storage system at the Brooklyn Army Terminal that will pave the way for adoption of distributed storage applications that could improve grid reliability, provide emergency power to critical systems, and manage peak loads. The City will continue to work with technology developers to determine how batteries can be safely and efficiently added to buildings.

Initiative 23

Improve backup generation for critical customers

During a power outage, it would be advantageous for the city if critical customers had backup generation in-place. It would also be advantageous for less critical users to be able to connect to backup generation.

The City, acting through the Office of Emergency Management (OEM), will expand its capacity to supplement the backup generation needs of critical and public interest customers, focusing separately on two tiers of need. The first tier—hospitals, nursing homes, police and fire stations, and wastewater treatment plants—already tend to have backup generation installed. Sometimes, though, this generation fails. OEM, therefore, maintains a fleet of mobile generators that it can deploy on short notice.

Facilities in the second tier—gas stations, pharmacies, food supply stores and other private customers that provide critical services that can be interrupted by extreme weather events—generally do not have backup generation, but may need it in the event of a widespread power outage. OEM, therefore, will coordinate with NYSERDA and Federal partners to develop a generator plan that uses a combination of incentives and regulations to pre-wire a subset of these facilities to accept generators and encourages these customers to rely on a combination of purchases of generators and generator supply contracts to enable availability in case of need.

In a separate but related effort, in the city's public housing developments, the City, acting through NYCHA, will install more than 100 natural gas-fired generators in buildings in the 100-year floodplain that have the greatest share of vulnerable residents.

— Credit: Seth Pinsky