PLANNING FOR A CLIMATE RESILIENT ELECTRIC BUS FLEET

Challenges and Solutions for Public Transportation Agencies

Image source: Can Pac Swire

ELECTRIFYNY

Tri-state Transportation Campaign

Mobilizing the Region

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INTRODUCTION

Climate change's accelerating timeline means our planet is in an increasing state of climatic volatility, requiring governments from nations to cities to focus current and future planning on climate-resilient infrastructure. Nothing has made this reality starker for residents of New York City than Superstorm Sandy, which brought the Metropolitan Transportation Authority (MTA), along with the rest of New York City, to a grinding halt in 2012. Quick thinking and coordination between emergency management organizations mitigated much of the disruption to residents' lives, but also demonstrated in real time the critical transportation link served by public transit buses, which became the backbone of the MTA during the crisis.

While Superstorm Sandy is, to date, the most significant test of the MTA's preparedness, the need for greater resiliency at the nation's largest transit authority is broader than historic hurricanes. Flooding and water table intrusion, asset damage, and service disruptions are challenges the MTA must ameliorate almost daily. Even beyond rare storms like Sandy, climate change is a real and regular risk to MTA operations. Planning and designing a truly climate-resilient transit system will reduce disruptions and damage during any future emergency the MTA faces.

Reducing New York State's contributions to climate change is a crucial transition the entire transportation system must undertake. Considering the need to not only prepare for a more volatile future, but also to work to prevent that same future from coming to pass, the MTA's commitment to electrifying their bus fleet by 2040 is a significant step towards a more prepared transit system.[1] As the MTA manages this transition, they do so with an eye toward fleet resiliency in the face of climate change. To that end, we offer an analysis of existing strategies, case studies, and future technologies that can ensure the nation's largest bus fleet is ready for the next storm.

Buses during Hurricane Sandy

The MTA's response to Hurricane Sandy began several days before the storm made landfall. Additional bus service was available, starting with evacuations of Flood Zone A, and continued until service was suspended during the storm.[2] The MTA allocated 200 buses to this pre-storm effort.[3]

Amidst the devastation the storm left behind, New York City Bus was the first public transportation back online—resuming service less than 24 hours after the storm on October 30 and operating fare-free. By the next day, October 31, buses were operating on normal schedules, but the system was over capacity, with long wait times due to traffic congestion, high demand, and reduction in other public transportation options.[4] Many bus routes required modified service because their roadways were blocked by trees, cars, and—unbelievably—boats.[5]

Shuttle Bus at Barclays Center, in Brooklyn, after Hurricane Sandy (Image Source: Metropolitan Transportation Authority)

Because buses deploy quickly, they were the first transit mode to get New York and the surrounding area moving again. Lower Manhattan was without electricity and the subways were flooded, so buses filled the dearth of transit into and out of the area.[6] Similarly, commuter buses from New Jersey into Port Authority Bus Terminal served as the prime public transportation linkage between the two states as many of the train tunnels between the two states suffered damage.[7] When the Midtown and Holland Tunnels reopened, they were designated for bus-only service during rush hours, further cementing the central role buses filled after the storm. This reliance on buses was evident on both sides of the Hudson: In the absence of train service, NJ Transit buses operated at 130% capacity. However, keeping buses operable required police-escorted convoys of fuel tankers through the streets of New York City—hardly an environmentally sustainable solution then, and much less so years from now.

Bus Bridges

By November 1, three days after Sandy's storm surge first hit New York City, the MTA had created the most important emergency transportation program: "bus bridges" across East River bridges. These temporary bus services took over from flooded subway tunnels and allowed people access between boroughs, particularly into and out of Brooklyn. After the New York City Department of Transportation (NYCDOT) established "dedicated bus lanes on the Manhattan and Williamsburg Bridges, Third and Lexington Avenues, and on Bowery and Delancey Street to better serve subway shuttle buses connecting Manhattan and Northern Brooklyn," they quickly saw "long waits (1+ hour) reported for subway shuttle buses in Brooklyn."[8] By creating these emergency bus bridges and prioritizing bus traffic with dedicated bus lanes, the MTA created a de facto Bus Rapid Transit system that allowed for similar travel patterns as the train system—so successful that demand exceeded their supply. During future crises, similar surface-level transit solutions may prove necessary, and the bus bridge model is also a potential solution to continued demand for public transit service and resultant congestion on trains and buses even outside of emergency scenarios.

Damage to the System & Repairs

Before the storm arrived, the MTA used mitigation methods to protect bus depots and assets, including moving buses from the Gun Hill depot in Baychester to higher ground and using sandbags and plastic sheeting to reduce flood risk at the Michael J. Quill Depot in midtown Manhattan.[9]

Effective preparedness planning prevented damage to rolling stock. However, there was significant flooding at the Quill, 126th Street, and Far Rockaway Depots. Far Rockaway storage and operations had to be relocated to the JFK Depot. Shuttle buses replaced A train service from November 11, 2012 until May 30, 2013 while the MTA repaired washed-out tracks, flooded stations, and signal equipment.[10]

Flooding from the storm surge demonstrated many of the vulnerabilities of the system, particularly electrical components of train tunnels and bus depots. As of winter 2020, many projects are underway or completed and will offer improved protection against the next storm.[11] The *Fast Forward* plan, published in May 2018, references specific design guidelines based on the MTA's experience during Hurricane Sandy to avoid the same problems.[12] However, this plan does not specify any resiliency planning for buses outside of capital improvements for bus depots.

Bus Bridge Recommendations & Service Expansion Needs

A New York University study recommended making the temporary bus lanes on East River bridges permanent, essentially expanding Select Bus Service lines to include the bridges to relieve congestion on the subway and provide redundant service for tunnel-dependent lines.[13] Creating this inter-borough bus service would have improved transit service and reduced dependence on the subways as the primary transit method over the East River.

This operation proved how vital bus operations are to the MTA: this response to Hurricane Sandy would not have been possible without the bus fleet's flexibility and reliability. The authority's transition to electric buses will allow the same flexibility of service, and with planning for emergencies, will allow the same reliability as well.

Coronavirus Pandemic

The years since Hurricane Sandy have brought additional challenges to bus service, but none more drastic than the coronavirus pandemic (COVID-19) that hit New York City in March 2020. Ridership on all transportation modes plummeted as the city shut down, but buses continued to provide the most service for essential workers. Bus service had a smaller decrease in ridership compared to commuter rail and subway, and were the solution brought in when the MTA opted to close the subway overnight for cleaning.[14] COVID-19 safety measures were easier to implement on buses; they swiftly implemented rear door boarding and, in turn, fare-free rides to protect operators and help riders distance where it was possible.[15] This dependence on bus service proves that regardless of the type of emergency, buses are the transportation option that New York relies on.

BUILDING RESILIENT BUS DEPOTS

Hurricane Sandy's destruction brought to light many weaknesses in bus depots and other infrastructure necessary to operate consistent, safe bus service. Looking ahead, it is crucial to prepare for electric buses and "harden" bus systems simultaneously, defined by the US Department of Energy as "…physically changing infrastructure to make it less susceptible to damage from extreme wind, flooding, or flying debris."[16] Areas hardest hit by hurricanes have focused on hardening their petroleum supply chains and other energy needs; these same principles apply to securing clean energy sources and supply chains.[17] The Department of Energy's guidelines indicate that hardening the bus system's built environment can be accomplished with various strategies: protection from the elements, modernization, general readiness, and storm specific readiness.[18] To meet these guidelines, electric bus planning must include weatherproof, redundant infrastructure and energy planning.

As of summer 2020, the MTA's bus depots need expansion and updates to store their existing fleet. Adding the capital investments needed to prepare them to charge, maintain, and store a new electric bus fleet is a massive financial undertaking. Competing budget priorities inherently constrain capital construction—now made more uncertain by the COVID-19 pandemic's economic impact.

Pantograph Charger for Electric Buses (Image Source: American Public Transit Association)

Electrifying Bus Depots

Electric bus charging is most often completed at bus depots when the buses are brought out of service—typically overnight, to take advantage of the cheapest electricity rates.[19] For context, one electric bus manufacturing company estimates that "it could take 150 megawatt-hours of electricity to keep a 300-bus depot charged up throughout the day. Your typical American household, by contrast, consumes 7 percent of that—per year."[20]

Resiliency requires prioritizing disaster readiness in long-range program strategy. LA Metro shifted to a practice of "adaptive design," which allows for iterative resiliency planning. This approach takes into consideration climate resiliency and what infrastructure is needed to plan for specific climate scenarios.[21] Any new construction project must consider climate change and resiliency during its design, but if financial restrictions prohibit full implementation, the feasible project must allow for future projects to fulfill the criteria.[22] This modular framework creates shovel-ready projects when funding becomes available. Given the resource constraints electric bus implementation may face in the future, this approach may alleviate upfront pressure.

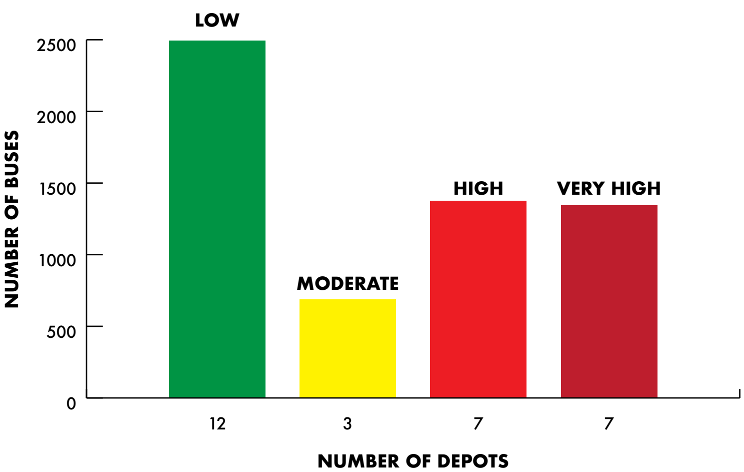


Figure 1. Bus Depots by Flood Risk. NYS GIS. GIS Data Set. June 2019. http://gis.ny.gov/gisdata/inventories/details.cfm?DSID=927.

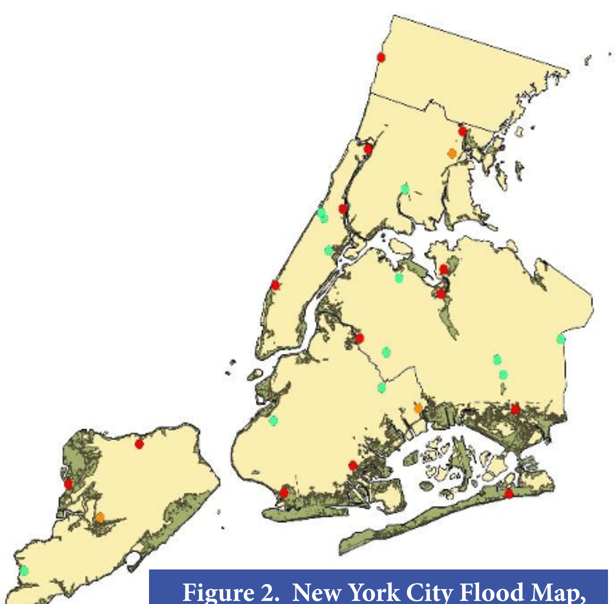


Figure 2. New York City Flood Map, Hurricane Sandy

Siting and Constructing Hardened Depots

The MTA already commits resources to improve the resiliency of their bus depots, including constructing flood walls and elevating power cables to reduce damage from storm surge during floods.[23] Because New York City is very close to sea level, many bus depots near the water's edge face the threat of flooding. While buses are assets that can be easily relocated in advance of storms—as we saw during Sandy—increasing storm severity and recurring flooding are still an issue for depot infrastructure and adding charging stations.

According to New York City flood plain data, seven bus depots (1,344 buses) are in a very high-risk flood zone based on 2050 flood projections and Hurricane Sandy inundation.[24] Another seven bus depots (1,375 buses) are in a high-risk flood zone. Three bus depots (687 buses) are in a moderate risk flood zone (flooding adjacent to property lines).[25] Based on the anticipated 2050 flood map, there will be 17 bus depots, with a total capacity for 3,406 buses, at-risk for flooding: more than half of the MTA's current bus fleet. As seen in Figure 1, more than

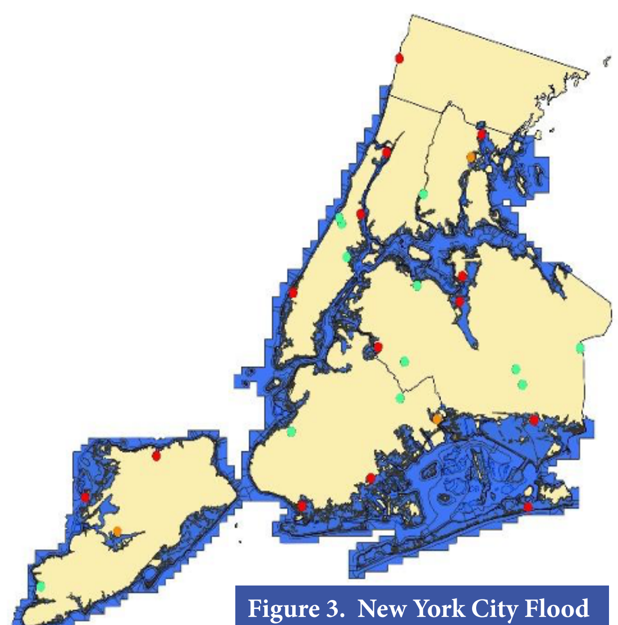


Figure 3. New York City Flood Map, 2050

half of the MTA's bus fleet is currently housed in depots at a high risk of flood damage. Figures 2 and 3 highlight the vulnerabilities most of the MTA's bus depots have, being located either in or adjacent to the Sandy and the 2050 flood zones. A full list of bus depots and their flood risks is available in Appendix A.

Relocating bus depots may not be feasible in the short-term, but given the lengthy implementation window for electric buses, the MTA should consider scaling up their charging infrastructure in moderate and low-risk depots before their investments in high and very high-risk depots. Given the long-term nature of this project, these decisions should be balanced with environmental justice and air quality considerations as well.

Mitigating Risks to Depot Charging

In best practice, chargers should be built on higher floors of bus depots and generally on any higher ground available to reduce flood risk.[26] One short-term mitigation measure would be to move to pantograph charging in bus depots. These chargers descend from frames built above the buses, which may reduce their risk of flood damage to the charging infrastructure.[27] Pantographs also allow buses in the middle of a depot to be charged instead of wall-mounted chargers (which only allow for charging on the sides of the depot), thereby increasing the number of buses that can be charged simultaneously. Pantographs are hung on frames that do not connect to the roof, which would also reduce load-bearing concerns on older building facilities and minimize the need for massive infrastructure construction projects.[28] Even so, given the flood risk for many bus depots, limited capital funds may be better spent constructing new depots in less flood-prone areas.

Pantograph chargers themselves may also be elevated to reduce the risk of flooding. For example, Miami bus garages installed their pantographs on concrete blocking to account for routine flooding in their facilities. Raising the concrete pads or elevation of charging equipment keeps these investments out of the flood plain and reduces their exposure risk during less severe flooding events.[29] The NYC Department of Environmental Protection is also working to raise their wastewater treatment equipment onto platforms, higher floors, or roofs, if available.[30]

Depots undergoing construction have an opportunity to incorporate resiliency during utility upgrades as well. When facilities fortify their electricity service, installing two feeds to the building makes the buildings less likely to be affected by an outage. Depending on availability, at least a portion of the chargers would still be operational in case one feed experiences a problem.[31] Antelope Valley Transit Authority takes this further: they run three meters, with one running from a solar network that powers the system for two-thirds of the year.[32] When the solar network is unavailable, their buses run on the other two meters, which each supply 20,000 amps—enough to charge 45 buses at one time.[33] Redundant charging opportunities improve charging resiliency in case of unavailability and reduce charging disruptions.

On-Site Energy Storage

Maintaining an energy source that is not grid-reliant can help reduce the impact minor power outages have on charging capacity. Many agencies across the country are using battery storage to achieve this redundancy and ensure uninterrupted service even during outages. Over time, battery storage costs can even be reduced: upcycled bus batteries can find a second purpose as energy storage once they have reached their useful life in operation. Martha's Vineyard will be installing battery storage with their on-route chargers to provide a partial backup in the case of a brief outage.[34] By charging these batteries using the existing substation off-hours, they plan to reduce peak load during busy service hours when multiple buses need to charge at once.[35]

Chicago Transit Authority (CTA) is studying battery storage as an option, but flags how massive the batteries must be to provide enough charge to act as a backup. Their initial bidding process to assess the market included an option for solar power capacity to charge the battery: their bus garages have flat roofs and are prime candidates for solar panels.[36] Currently, they are predominantly studying the feasibility for these batteries at their bus depots due to the battery's size and their potential to reduce peak electrical grid usage during periods of heavy charge needs.[37]

However, battery storage is not helpful without an ability to recharge in case of an extended utility disruption. As an absolute backup, transit agencies are considering diesel generators to allow for fleet charging if no other power source is available:[38]

- During Albuquerque, New Mexico's electric bus pilot, they estimated that emergency generators could power about thirty percent of the agency's bus fleet during a blackout.[39]
- In Southern California, Antelope Valley Transit Authority purchased a 1.3-megawatt generator, which can charge their entire fleet of 88 buses for two days.[40]
- Also in Southern California, Foothill Transit's In-Depot Charging and Planning Study recommends permanent diesel or fracked natural gas-fired backup generators. The generators can be parked in bus stalls immediately adjacent to the power service points and connect to the distribution boards to supply power in place of electrical service. They should nominally provide 2 MW in capacity, but smaller generators would be acceptable based on the actual number of electric buses needed. For example, in 2024 a 150 kW to 300 kW generator would be the minimum recommended size. To ensure redundancy and increase resilience, depots may want to include two 1,500 kW gas fired emergency generators at each depot to allow for enough buses to be available for many scenarios. Rooftop solar at some of their depots would provide about 5% of the power.[41]

While not a sustainable fuel source, generators do allow operations to continue during an extended outage by refilling the diesel generator to gain additional charging capacity. These onsite generators would allow for continued operation of a fleet during an emergency event, heat wave, or unexpected outage and build resiliency into the transportation system. Utilizing portable generators for extended outages is another option; they are cheaper and more flexible, and most power outages at depots are brief and only affect some, but not all, depots.[42] This allows the purchase of only a small number of these backup generators, and then they can be set up when and where they are necessary. Given their availability, the Federal Transit Administration also issued a report in 2019 regarding the potential to use hybrid buses as emergency generators.[43] Their proliferation in the past decade means these vehicles may be able to function as emergency backup past their operational useful life. However, as the transportation industry transitions away from diesel, transportation authorities will need to reconsider their emergency backup plans once alternative options become available.

ELECTRIC BUS CHARGING CHALLENGES & TACTICS

Out of Service Buses caught in the snow in Edmonton, Canada (Image Source: Canadian Broadcasting Corporation)

Changing fueling systems is a massive undertaking for a bus fleet. "Range anxiety," often referenced when discussing light duty vehicle electrification, is a concern for electric buses operating along routes that are not designed to their capacity as well. The charging network each transit authority designs must address its unique array of challenges and be developed with emergency planning agencies to reduce range concerns and service disruptions. Based on the experiences of other cities, the MTA can expect to address cold weather, grid interruptions, and fluctuations in energy demand in their their electric bus fleet operations plans.

Charging in Cold Weather

Much of the consensus around light-duty electric vehicles recommends keeping the vehicle inside to reduce battery drain, which is an operating assumption that transit agencies have considered when planning for electric buses as well. Many bus depots in North America and Europe depend on outdoor space for storage, but they have found solutions to allow for efficient charging even during severe cold weather events.[44] When installing the charging infrastructure, adding heaters to the chargers and to the bus ports reduces ice buildup in climates with severe winters. Some high voltage chargers are liquid-cooled, which allows the system to also use liquid heating in cold weather to operate in an extreme range of temperatures.[45]

A longer-term challenge is hoteling the buses once they have charged to reduce battery drain, as storing a bus outside when it is powered off may lead to reduced battery capacity once the bus is turned back on. Gantry systems inside bus depots to keep charging the buses at a low rate and allow for conditioning the cabin before service may be a more cost-effective solution to installing high voltage bus chargers inside.[46] Starting a bus with a cold battery significantly reduces the range while in operation, so some agencies have created plans to ensure a bus leaving the depot has a warm battery and accounts for any charge loss during cold weather. For example, Antelope Valley Transit Authority worked with bus manufacturer BYD to create a "pre-warming" system on the bus chargers to avoid vehicles beginning service with cold batteries.[47]

Smart Charging

Smart charging is a technology that allows electric buses to use grid resources more efficiently and makes incorporation of renewable resources into agencies' electric power portfolio easier.[48] This technology adjusts charging rates so electric buses charge quickly with high power during lower-use times, allows for storage during high generation but low-use times, and will stop charging or do so at low power during peak times. Electric bus smart charging may increase the efficiency of our electrical system, providing a stable investment for utilities as well.[49] At this time, electric bus pilots and early integration allow for grid capacity testing and frame which upgrades will be needed for fleet expansion. Additionally, this technology may be integrated with outage monitors, so fleet managers are able to see electrical outages during emergencies and preempt issues with everyday service. This data may highlight pinch points and frequent outages to better prepare infrastructure against emergencies.[50]

Electric Bus Charger in Brooklyn, NY (Image Source: Metropolitan Transportation Authority)

On-Route Charging

When there is an electrical outage in part of the MTA service region, select depots will not be able to charge their buses. On-route chargers provide redundant charging access to keep electric buses in service if their depot is out of commission. Some experts feel that on-route charging is the resiliency gold standard because their dispersal through the city provides charging availability during a widespread emergency: These chargers do not rely on one specific energy grid or centralized location to charge the fleet.[51] Once a location for an on-route charger is sited, planning for high electrical capacity and estimating two to three times as many chargers at that location as current service requirements call for may reduce strain when electric buses have to rely on these chargers in the case of an out-of-service depot.[52] According to Antelope Valley Transit Authority, inductive on-route chargers are able to recover two miles of range for every one minute of charging, allowing a 10-minute stopover to charge a bus for an additional 20 miles. This creates a viable alternative continue to run service on high frequency, high usage routes that are essential to the bus system.[53]

However, on-route charging typically carries higher infrastructure and electricity costs than depot charging.[54] Siting these chargers requires planning to triangulate routes nearby and allow enough redundancy in grid capacity to provide more charge than necessary for daily operations.[55] For the MTA, deployment of on-route charging on high-frequency, high-ridership routes—alongside robust street priority measures like dedicated bus lanes, bus-only parking zones, and charging at high-frequency bus stops—would offer the most return on investment for on-route charging infrastructure.

Inductive Charging

Inductive charging is a touchless charging option with a plate installed in the roadway that allows a vehicle to charge during a route by stopping over the plate.[56] Martha's Vineyard has begun installing inductive charging infrastructure as of 2020, and Stockholm began piloting the technology on one of its bus routes in 2018.[57] While much of the charging infrastructure is underground, inductive charging requires many of the construction considerations an overhead charger would require, including utility upgrades to the site.[58]

Inductive charging installations are predominantly installed under the road surface in the street and are designed to be flooded, snowed on, and generally to stand up against routine weather events.[59] Its infrastructure vulnerability is the same as other in-route charging: the large electronics container nearby containing its transformer and other components. These are generally considered weatherproof, but are not floodproof. As such, transit authorities are siting them well away from any flood zones.[60]

An Electric Bus Charging Wirelessly in Wenatchee, WA (Image Source: www.electrive.com)

Stockholm, Sweden recently concluded a pilot of inductive charging with a prototype electric bus and electric charging pads from Bombardier.[61] Their conclusions focus heavily on the technology's immaturity. Inductive chargers are wireless, but they still require the bus to lower the bottom of the bus within three inches of the charging pad. Where Antelope Valley Transit Authority have not seen issues with their electric buses kneeling to come in range of the charger, Stockholm's Transit Administration found that the lifting mechanisms were not robust enough to withstand their winter weather conditions. Salt, sand, and ice rendered them unusable to the point that in their final report, they included the feedback from operators that "It's nice—when it works."[62] Understanding the Northeast's sometimes challenging winters, their experience suggests that inductive charging may not be a market-ready option for New York.

DEPLOYING AND OPERATING A RESILIENT FLEET

Buses bring flexibility that fixed transit options cannot, making them the workhorses of any system. During a hurricane or similar storm, downed trees and inaccessible roadways require rerouting buses to avoid hazards and reducing service in case of driver shortages. On the charging side, reduced service means that more buses are in the depots at a time, which allows for more spread-out charge times. If the buses are available to charge over 24 hours instead of within an eight-hour window off-peak, the depot can reduce peak load and put less strain on the grid.[63]

Defining the level of operations a transit authority will expect in an emergency informs contingency planning for electric buses. For example, Foothill Transit's emergency plan calls for at least 50% of buses to be available during an extended outage.[64] LA Metro is updating their Climate Action and Adaptation Plan to define their operating requirements, so their operators can satisfy service requirements in a transparent way during emergencies.[65] They also have begun implementing "blue water" detours where service that runs through frequently flooded areas have standing reroutes to reduce recurring service disruptions.[66] Clear expectations and communication with the riding public will allow electric buses to seamlessly continue the reliable service transit authorities expect from their bus fleets.

Bus Range Expectations

Regardless of propulsion type, bus mileage expectations vary depending on temperature, route topography and number of stops.[67] Best practices suggest maintaining a fuel reserve during regular service to reduce service disruptions and maintain a level of preparedness. Electric buses have a 100-mile per charge expected range, and transit authorities such as CTA are operating 60 to 80 miles at a time per rush period.[68] Transit authorities' consensus is to operate with a 15-20 percent buffer zone to account for deadhead time back to the bus garage and any unplanned needs along the route.[69]

Additionally, CTA has written their electric bus procurement and planning processes to account for the specific route that the bus would serve.[70] This allows them to test the vehicle's battery capacity in an operational setting instead of relying on the original equipment manufacturers' mileage estimates. Oversizing battery capacity during procurement helps preempt resiliency needs and gives transit authorities some flexibility during an emergency.

Operations Seasonality

Electric buses face significant limitations in colder weather. Energy drain from running electric heaters and cold batteries can cause transit agencies to hold off on relying on them for year-round use. However, many cold-weather transit agencies have found success with updated electric bus models that are designed to reduce drain on batteries and make them more resistant to cold: even Anchorage, Alaska piloted an electric bus in 2018.[71] Edmonton Transit Service (ETS) and CTA have both seen successes with electric buses in winter.

ETS conducted rigorous testing on multiple electric bus companies, concluding that it is feasible to operate electric buses in their winter conditions.[72] Their results showed that outdoor temperature did have an impact on the electric buses' energy consumption, but it was much smaller than anticipated. Their study concluded that electric bus propulsion was not affected by cold weather as much as single occupancy electric vehicles. They utilized mitigation techniques to give the buses as close to ideal conditions as possible: the electric buses used diesel heaters to eliminate heat draw from the battery, buses were stored in a heated depot, and the buses were equipped with software to monitor the battery temperature to keep it in an optimal range.[73]

CTA began testing two New Flyer 40-foot battery electric buses through their winters in 2014.[74] They too found that if they included diesel-fueled heaters to help warm the buses, they could reduce strain on the bus's range; up to fifty percent of the energy the buses consumed went to HVAC without the diesel-fueled heaters, which made the buses untenable.[75] With the diesel heaters, they saw a reduction in range closer to twenty percent compared to the battery testing results from the Penn State Bus Research and Testing Center, which does not account for passenger load and HVAC needs.[76] It is also important to note that many tests occurred using prototypes and first-generation vehicles from bus manufacturers, so some issues of battery life were able to be resolved in real time.[77]

With many success stories reported from areas with similar and more severe weather than New York, the MTA can feel more comfortable with electric buses' ability to handle extreme winter weather events and find solutions to make a full electric bus fleet operate in any situation. While an electric heater run on diesel is not optimal from a sustainability lens, bus companies have shown commitments to creative solutions to issues transit agencies continue to find in the real world.

THE ROLE OF UTILITIES

Robust electrical utility infrastructure is vital to the success of electric bus fleets.[78] Hurricane Sandy disrupted one-third of the city's electrical capacity and the resulting flooding from the storm shut down five transmission substations.[79] A major blackout or reduced capacity would pose challenges to operating electric buses. Subways are also impacted by flooding and signal outages, meaning a large storm could freeze the public transportation system. Consolidated Edison (ConEd), the utilities provider in New York City, will need to be heavily engaged in any plans for full fleet bus electrification.

In California, utilities have engaged in significant investment to provide support for transportation electrification. The ban on utility investment in electrification by way of infrastructure ownership was lifted in 2014, and in 2018 the state's public utilities commission approved significant funding to support such investment. California provides funding and rebate programs to its utility companies to invest in expanding EV infrastructure, and some utilities are experimenting with different rate structures that better support EVs.[80] In the case of Foothill Transit, Southern California Edison has committed to fund all distribution system upgrades and line extension upgrades to the new Foothill charging equipment.[81]

Utility coordination extends past initial investment. Demand charges are a threat to transit budgets as more electric buses are brought online. While many mitigation efforts are underway to reduce peak use and the costs that come with it during regular operation, emergencies bring financial uncertainty. Emergency planning collaboration must be a part of utility discussions. A flat rate during states of emergency would be one way to reduce the financial impact to transit authorities.[82] The MTA has begun this process, requesting a separate service classification for Medium and Heavy-Duty Vehicles in their April 2020 comments on the Public Service Commission's electric vehicle proceeding.[83] As a public good, it is essential that public transit be able to afford to operate during and after emergencies.

Grid Resilience

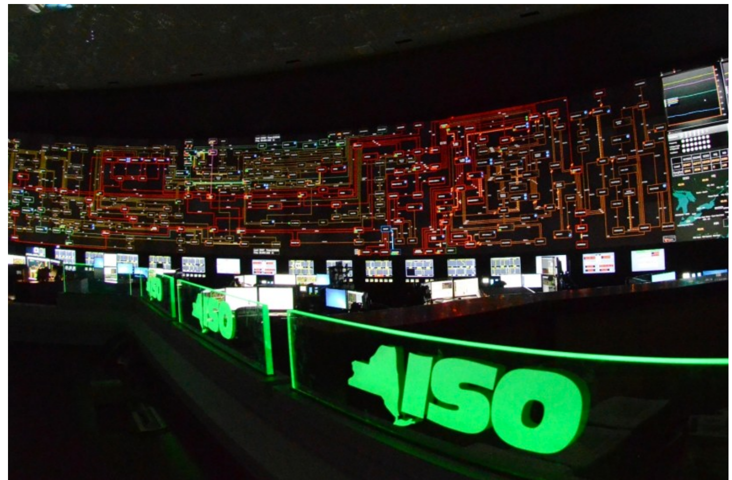
New York City already consumes more power than it produces, which makes the electrical grid reliant on transmission from upstate New York and Long Island. The New York Independent System Operator, which oversees electricity distribution throughout the state, is working to increase the number and capacity of transmission lines from upstate New York to New York City. Ongoing capital planning related to the proliferation of renewable energy should be tied into the push for resilient electrification infrastructure.[84]

ConEd has been working to improve its energy infrastructure in the face of climate change, spending $1 billion in the past few years on resiliency upgrades. This includes upgrading power lines, installing wires and poles that can withstand high wind speeds, reinforcing tunnels to protect electric feeders, and adjusting the grid so that the most flood-prone areas will not affect the ability of the rest of the grid to deliver electricity to other parts of the city. By the end of 2020, ConEd will produce an implementation plan to continue to improve climate resiliency based on a 2019 vulnerability study. The plan will address resilience in the face of many weather events: storm surges, sea level rise, inland flooding, heat waves, and high wind speeds. Preparing for these events creates support for resilient electric bus infrastructure and a grid that may support a full fleet of EV buses.

Currently, ConEd's Electric Long-Range Plan does not include any mention of medium or heavy-duty vehicles, but does discuss the increased use of electric vehicle technology and the need to prepare the grid for large-scale transportation electrification. These recommended improvements include "delivery system reinforcement to manage additional peak demand growth, new connections to connect [EV] chargers to the delivery system, and the construction of [EV] charging stations in convenient locations."[85] This report estimates that ConEd should spend $280 million over the next 20 years in these areas—although more investment will likely be necessary. The continued delivery of electricity from upgrades would keep buses running in an emergency, particularly in flooding or storm situations where getting enough diesel would prove difficult.

Power Requirements and Grid Capacity

Plans for fleet electrification are moving forward with significant unknowns around how to integrate medium duty vehicles into the grid: how much integration might cost, what level of electricity use may be required, and what facility upgrades will be necessary. Information from other cities is available, and some models are emerging as electrification gains traction across the country.



Control Room at the New York Independent System Operator (NYISO) (Image Source: www.smwllc.com)

Currently, Con Ed estimates that the grid's peak capacity for all uses in summer is approximately 14,500 MW of power, with a winter peak capacity of approximately 8,300 MW. Except on the hottest days of the year, this leaves at least 6,000 MW of flexibility in the capacity distribution. However, this does not account for physical constraints, last-mile distribution, or solutions for the heat waves that already result in black- and brown-outs, which are proving more frequent and more severe.[86] Last mile distribution is the connection from the substation or transformer to the final point of use, and it can be overloaded if multiple depots or charging points are using the same substation, and may cause damage or overloading. To avoid overloading and to increase redundancy, depots should not be overcrowded or clustered.[87]

RESILIENT ENERGY SOLUTIONS

Offshore Wind Power (Image Source: David Dixon)

On-site energy storage is helpful for short-term situations, CALSTART argues, but will not assist in an emergency lasting weeks or months.[88] Truly resilient electric buses will require energy sources that are highly unlikely to be disrupted or unavailable. Pilots for microgrids are underway across the United States and including renewable energy sources may allow for clean energy generation closer to where transit authorities need it.

Electric buses also provide a resource that diesel buses cannot: They are able to act as battery storage and provide energy back to the grid. This reciprocal relationship diversifies their value during an emergency. Emerging technology has the potential to change the relationship between vehicles and energy altogether.

Renewable Energy and Microgrids

Resiliency for charging electric buses may include access to renewable energy funneled directly to chargers. Antelope Valley Transit Authority has been a leader in this field, charging their electric buses on a nearby solar field for two-thirds of the year, with future plans to convert all of their charging to solar fields and battery storage by 2022.[89] LA Metro is focused on establishing microgrids as an adaptation mechanism to improve its system's redundancy.[90] The MTA has been utilizing solar panels on the roofs of bus depots and warehouses since 2008, making this a proven technology that is already part of operations.[91] The Earth Day Request for Proposals issued by the MTA in 2019 pushes this much further, including "solar development of seven MTA properties . . . generating an estimated 6.5 megawatts of emissions-free electricity for thousands of New York households."[92] While much of this solar development is intended for revenue generation via energy sales to private companies, there is space to work with emergency service planners and utilities to allow for solar energy to be transferred to a microgrid format during emergency situations. At the current time, however, the MTA does not own enough rooftop property to allow microgrids to supply the full charging needs of its bus fleet, and due to near-complete urbanization of its operating geography, it is unlikely to own such property in the future. The role for utilities and municipalities in assisting in developing the necessary charging infrastructure and ensuring affordable charging rates is critical for the future of any electric bus fleet in highly urbanized areas like New York City.

As of April 2020, offshore wind planning is becoming a reality near New York City, particularly off the coast of Long Island. The 2020-21 New York State enacted budget includes policy to move offshore wind projects forward to achieve the Governor's goal of 9,000 MW of offshore wind energy generation by 2035.[93] More localized energy generation allows for a more resilient grid for the entire New York metropolitan region, and may be able to account for up to one-third of electricity capacity for New York City in the future.[94] As these projects begin construction and utilities update their transmission plans, it will be vital to include emergency planning components to ensure electricity availability to charge buses during periods of high demand or outages.

Buses as Power Sources

In an emergency, electric buses can serve as mobile batteries in affected communities, creating microgrids to keep electricity flowing to vital places such as hospitals and nursing homes until further emergency aid arrives. While electric buses have not been tested in emergency scenarios, Japan tested plug-in vehicles (PEVs) to create microgrids after the Fukushima Daiichi nuclear meltdown in 2011. With such a large source of power offline, Japan suffered from rolling blackouts. Many hybrid owners used auxiliary AC plugs available in their cars as a source of emergency energy, essentially turning them into generators. Fully electric vehicles have large batteries, allowing them to store enough electricity to power entire homes and even businesses.[95] In the years following Fukushima, several test programs were established in the hopes of laying the groundwork for potentially massive EV energy storage projects.

When coupled with smart grid technology, a PEV can act as a load as well as a distributed storage device utilizing an on-board bidirectional battery charger. Being connected to the grid when not in use, the battery of the PEV can supply power at peak load times and thus increase the power reliability of the grid. This technology is called Vehicle to Grid (V2G).[96]

To use an electric bus to create a microgrid, it must have Vehicle-to-Grid capability (V2G). Most electric buses equipped with this are school buses. Fleet vehicles in general and school buses specifically are by far the vehicles best suited for V2G applications. School buses have defined routes of limited range and very predictable time of use: during school days they bring children to school in the morning and back home in the afternoon. The other 17 hours of the day they can be plugged in, provide V2G services, and collect revenue.[97]

Vehicle-to-Grid Use Cases

V2G could help to make an energy grid more resilient by supplying electricity during times of peak use. That includes when renewable energy resources are unavailable, such as at night, when solar panels aren't functional but plenty of vehicles are sitting idle.[98]

Resiliency is not just for extreme weather events: it is necessary to reduce stress on the electricity grid and on the transit system as electric buses become the majority of fleets. By creating microgrids with electric buses, energy storage and V2G can help reduce demands, be there for communities that may need backup power, and reduce disruptions to service when situations arise.

New York - White Plains School District

The district's Lion Electric Co. buses are equipped with bidirectional inverters, meaning they can charge an electric bus or store energy in the bus battery to feed back into the electrical grid, taking cues from smart software technology and chargers developed by San Diego-based Nuvve Corp.[99] Since school buses do not operate year-round and have significant idle time during the year and full-time during summer, they make the perfect backup battery to help supplement the electricity grid.[100]

According to ConEdison, this V2G option will allow five bus batteries to store 75 kilowatts of power during summers to charge the batteries during low-demand times and draw from the batteries during peak times in the afternoons.[101]

California- University of California San Diego

At the University of California San Diego, V2G technology provider Nuvve is executing a pilot program called INVENT, funded by the California Energy Commission, to install

Electric School Buses Charging (Image Source: New York Times)

50 V2G bi-directional charging stations around the campus.[102] This program would allow vehicles parked on campus to become part of the campus's electric grid during the day, helping with peak energy usage as needed. According to UCSD, "Drivers would be paid every time the grid operator uses energy from their cars while still being guaranteed the expected level of charge needed to operate the vehicle."[103]

The INVENT program takes this one step further by using UCSD's solar forecasting technology to charge electric vehicles based on when renewable energy is most available to use as many "'green' electrons as possible."[104] This sort of smart tracking has implications for electric bus charging, as such a large number of vehicles charging at a time could transform the way the electrical grid is managed, ensuring that all renewable energy is prioritized and used first.

Emergency Back-Up Fuels

Emergency planning requires significant coordination between first response agencies, including fire, police, and emergency medical services. Any transition away from traditional fuel sources must consider the intertwined plans that these agencies have in place. In the case of Hurricane Michael, Florida transit agencies served as the fuel reserves not only to keep their buses running, but also to fuel police vehicles.[105] It is essential to be prepared for emergencies even as all public fleets are on different timelines to electrify. Looking forward, the same agreements must be considered to build in resilient charging facilities for all vehicles needed for emergency response and consistent operation.

As trucking is the most utilized delivery method for New York City, there should also be further analysis done regarding other fuels that are able to be delivered by truck other than diesel. For example, hydrogen can fuel electric generators and is a renewable energy source.[106] Hydrogen is still an emerging technology, but start-ups are beginning to create products that may bridge the gap between traditional fuel sources and the electrical requirements for full zero-emission transportation.[107]

Houston, Texas was dramatically affected by Hurricane Harvey in August 2017, bringing unprecedented levels of flooding and damage. Their diesel and gasoline deliveries rely on those roads, so it became imperative to have an alternative that did not rely on infrastructure that could flood.[108] Texas has a particularly developed network of fracked natural gas infrastructure that allowed for compressed natural gas (CNG) deliveries to keep their bus fleet running.

Any major transition, including electrifying the MTA's bus fleet, requires back-up plans. While New York City has some access to natural gas pipelines which may make CNG buses a reality in disaster scenarios, the underlying lesson from Houston is to create reliable backup power options that do not rely on roadways.[109] If transportation authorities are investing in new, resilient infrastructure, it will be more effective to install renewable and zero-emission backups to reduce increased reliance on fossil fuels. With almost all of New York City's freight traveling via the George Washington Bridge, the Goethals Bridge, and the Lincoln Tunnel, resiliency means finding other ways to power buses when roadways are not available.[110] Waterways, railways, and pipelines must all be analyzed to see their feasibility in emergency scenarios.[111]

SUMMARY AND RECOMMENDATIONS

No matter the emergency, transit authorities do not yet have the plans in place they need to be prepared for a changing world. Hurricane Sandy showed many of the flaws in the way we store, maintain, and fund transit—and many of these issues have not been solved. Plans for future storms must be put in place as the MTA moves closer to its 2040 deadline to electrify its bus fleet. Fortunately, many of the same strategies and investments that will improve electric bus resiliency will assist in improved day to day service as well.

Future Planning: Strategies and Guidelines

New York's general emergency preparedness framework is successful because of advance decision-making and communication between agencies. Given its publication date, the MTA Climate Adaptation Task Force Resiliency Report from 2017 does not include electric buses in their adaptation plans.[112] Due to the relatively small amount of damage to New York City Transit buses and the MTA Bus Company, the report is predominantly focused on train infrastructure. This report also does not break out all the resiliency projects that the MTA undertook to rebuild and improve their hurricane response.[113]

Bus depots are traditionally low-risk investments as most of the space is designated to bus storage. As the most expensive asset in the building, buses can be evacuated and eliminate the risk of flood damage. Moving forward, it is essential that any resiliency planning include provisions for electric bus infrastructure that may be at risk, as well as additional capital investments the MTA may undertake to better operate their new buses. The NYC Wastewater Resiliency Plan is the NYC Department of Environmental Protection's response to Hurricane Sandy and breaks down their resiliency infrastructure projects by cost as well as efficacy.[114] They also calculate the cost of protective measures per location, cost of damage without protection and the amount of financial risk that would be avoided over 50 years.[115] This matrix, along with specific infrastructure considerations for each of their locations, would be an exceptional way to prepare operations staff and decisionmakers for electrified bus depots and what they mean for the MTA's overall emergency preparedness.

LA Metro took a different strategy, choosing to score their infrastructure on its resiliency and find gaps using its Resiliency Indicator Framework.[116] This Framework uses "Resiliency Principles" to define an infrastructure's preparedness within six groups: Robustness, Redundancy, Safe-To-Fail, Change Readiness, Networks, and Leadership and Culture.[117] The MTA has a unique opportunity to frame out its existing infrastructure and investment needs before construction begins to preempt future damage to its infrastructure.

RECOMMENDATIONS

Lessons from Hurricane Sandy

- Provide on-street bus priority for high-frequency, high-ridership routes with charging infrastructure.
- Utilize ad hoc Bus Rapid Transit routes to create redundant public transit routes with subways to reduce service disruptions.
- Install permanent bus lanes on bridges, over the East River in particular, to provide redundancy with subway tunnels.

Bus Depot Investments

- Put most of electric bus charging infrastructure in flood-resilient bus depots and ensure all bus depots are flood-resilient long term.
- Construct charging infrastructure to be as flood-proof as possible, siting chargers on high floors, from pantographs, or on platforms to reduce damage.
- Install multiple electrical feeds to each depot to continue access to electricity in case of a regional outage.
- Investigate on-site energy storage options, including batteries and generators.

Charging Strategies

- Create a charging schedule that reduces the need to “hotel” charged buses before their deployments and condition them before service to reduce battery drain.
- Invest in smart charging technology to reduce peak demand, save money, and allow for renewable sources to integrate with the electrical grid.
- Incorporate redundancy into on-route charging capacity to allow for service expansions and potential support during electrical outages at depots.
- Develop an on-route charging system that allows high-frequency, high-ridership routes to continue operation during emergencies or electrical outages.

Fleet Deployment

- Communicate alternate routes that buses will use in high flood risk areas.
- Plan routes for electric buses that allow for a cushion between needed and available range to account for service disruptions, driver braking habits, and unforeseen circumstances.
- Explore microgrids using existing renewable solar infrastructure for extreme emergencies as well as on-site battery storage for short-term events and reducing peak demand during strained grid times, such as extreme heat waves and brown-outs.
- Reduce battery draw due to HVAC needs to make electric buses more feasible. If heat is drawn from the battery, reduce or turn off heat during electricity shortages and blackouts to improve range by up to 15%.

Utilities’ Role

- Work with utilities on depot electrification and grid preparedness, eliminating high demand charges during emergencies through an agreed-upon flat rate during states of emergency to keep buses running and not bankrupt everyone.
- Eliminate demand charges for transit authorities and negotiate a flat rate for electricity during states of emergency.
- Continue resiliency construction and build capacity to account for bus charging during peak energy times.
- Ensure that depots all operate on different substations to reduce outage risks and strain on the electrical grid.
- Develop additional renewable energy sources in the state to support increased grid load.

Energy Opportunities

- Explore the option that MTA's existing solar inventory may be made available during electrical outages to help power depots.
- Coordinate with state agencies to secure renewable energy transmission for electric bus operations as it becomes available.
- Find opportunities for electric buses and hybrid buses to serve as power sources for other essential services.
- Consider alternate fuels for backup generators, particularly renewable sources but also including compressed natural gas and hydrogen, to eliminate the MTA's reliance on diesel.

Looking Ahead

At this time, resiliency planning in public transit has not been fleshed out in a meaningful way. Climate change highlights what transit must prepare for: increased heat index days, flooding, windstorms, and more. Electric buses have the unique ability to assist in slowing these effects and assisting as these changes to our environment continue. They also help reduce the health impacts of climate change, reducing exposure to particulate matter, nitrous oxide, and other harmful pollutants. The MTA's transition to electric buses is contingent on cooperation and planning with their utility partners to ensure the long-term success of this new technology. This will be a historic transition for the MTA—and the ideal opportunity to prepare for what the future holds.

Appendix A: Flood Risk for MTA Bus Depots

Depot	Number of Buses	Risk
JFK	234	Very high
Michael J. Quill	276	Very high
Ulmer Park	241	Very high
Casey Stengel	234	Very high
Far Rockaway	99	Very high
Meredith Ave	73	Very high
Grand Ave	187	Very high
Castleton	216	High
College Point	311	High
Flatbush Depot	235	High
Mother Clara Hale	130	High
Kingsbridge Depot	266	High
Eastchester Depot	136	High
Yonkers Depot	81	High
Gun Hill Depot	283	Moderate
Yukon Depot	269	Moderate
Spring Creek	135	Moderate
West Farms	334	Low
East New York	242	Low
Fresh Pond	197	Low
Jackie Gleason	284	Low
Amsterdam	26 (museum)	Low
Manhattanville	229	Low
Tuskegee Airmen	140	Low
Jamaica Depot	209	Low
Baisley Park	111	Low
LaGuardia	247	Low
Queens Village	270	Low
Charleston	204	Low

WHO WE ARE

ElectrifyNY is a statewide coalition of advocates for environmental justice, public transportation, social justice, and good jobs fighting for a clean, equitable electric transportation future for New York.

New York City Environmental Justice Alliance

Founded in 1991, the New York City Environmental Justice Alliance (NYC-EJA) is a non-profit, 501(c)3 citywide membership network linking grassroots organizations from low-income neighborhoods and communities of color in their struggle for environmental justice. NYC-EJA empowers its member organizations to advocate for improved environmental conditions and against inequitable environmental burdens by the coordination of campaigns designed to inform City and State policies.

Tri-State Transportation Campaign

Tri-State Transportation Campaign fights for an equitable, safe, multi-modal transportation network that provides options and supports the economies of New York, New Jersey, and Connecticut.

Environmental Advocates of New York

Environmental Advocates of New York's mission is to protect our air, land, water, wildlife and health. Celebrating its 50th Anniversary, EANY monitors state government, evaluates proposed laws, and champions policies and practices that will ensure the responsible stewardship of our shared environment. EANY works to support and strengthen the efforts of New York's environmental community and to make New York a national leader.

Sierra Club

The Sierra Club is America's largest and most influential grassroots environmental organization, with more than 3.5 million members and supporters. In addition to protecting every person's right to get outdoors and access the healing power of nature, the Sierra Club works to promote clean energy, safeguard the health of our communities, protect wildlife, and preserve our remaining wild places through grassroots activism, public education, lobbying, and legal action.

Jobs to Move America

Jobs to Move America (JMA) is a strategic policy center dedicated to building an equitable, sustainable society by creating good jobs for all. Our research has been used by policymakers in cities and states across the country to ensure that public investment in infrastructure counters climate change, holds corporations accountable, and expands access to good, clean jobs for all working people. We have built powerful coalitions of labor, community, and environmental groups to advocate for equitable policy solutions that offer a roadmap to transforming our economy.

Sustainable Westchester

Sustainable Westchester is a collaboration of Westchester County, NY local governments that empowers municipal leaders, concerned citizens, businesses and local organizations to partner in the development of sustainability initiatives and share tools, resources, and incentives for healthy, vibrant and attractive communities now and in the future.

Natural Resource Defense Council

NRDC works to safeguard the earth—its people, its plants and animals, and the natural systems on which all life depends.

Long Island Progressive Coalition

A grassroots community-based organization dedicated to promoting sustainable development, revitalizing local communities, enhancing human dignity, creating effective democracy, and achieving economic, social and racial justice.

New Yorkers for Clean Power

New Yorkers for Clean Power (NYCP) is a statewide collaborative campaign to rapidly shift to a clean energy economy.

ALIGN New York

ALIGN is a longstanding alliance of labor and community organizations united for a just and sustainable New York. ALIGN works at the intersection of economy, environment, and equity to make change and build movement. Our model addresses the root causes of economic injustice by forging strategic coalitions, shaping the public debate through strategic communications, and developing policy solutions that make an impact.

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