**A cover of a power line

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­**Acknowledgements**

This work could not have been completed without the support of everyone at the Office of Congresswoman Yvette Clarke. I would like to give a special thanks to Legislative Director Steven Blattner, who played an invaluable role in helping me get this project off of the ground. To former Legislative Assistant Sierra Fuller, I can’t begin to express my gratitude for all of your help with amassing resources and setting on a direction for the thesis.

At the University of Virginia Frank Batten School of Public Policy, I’d like to extend my thanks to Daniel Player, associate professor of public policy, and Gerard Robinson, professor of practice in public policy and law, for their thorough and attentive feedback throughout the course of the year. Their individualized attention made all the difference in the completion of my APP. To Bill Shobe, research professor of public policy, thank you so much for your generous and thoughtful suggestions throughout the ideation, research and writing process.

Finally, to my family — Elizabeth Caso, Henry Caso, Thomas Caso, Barbara Buchalter and Jane Godiner — thank you for your endless support at every stage of completing this thesis, and throughout my time at Batten. I am sincerely grateful.

**Honor Statement**

On my honor as a student, I have neither given nor received aid on this assignment.

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Charles Caso

**Disclaimer**

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, by the Office of Congresswoman Yvette Clarke, or by any other agency.

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**Abbreviations**

AC – Alternating current

CAES – Compressed air energy storage

DC – Direct current

DER – Distributed energy resource

DLR – Dynamic line rating

DOE – Department of Energy

EIA – Energy Information Administration

EJ – Environmental Justice

EMS – Energy management systems

EPA – Environmental Protection Agency

EV – Electric vehicle

FEMA – Federal Emergency Management Agency

FERC – Federal Energy Regulatory Commission

GHG – Greenhouse gas

GW – gigawatt

GWh – gigawatt hour

HVAC – Heating, ventilation, and air conditioning

IEA – International Energy Agency

ISO – Independent system operator

LNG – Liquified natural gas

LPO – U.S. Department of Energy’s Loan Programs Office

MW – megawatt

MWh – megawatt hour

NEPA – National Environmental Policy Act

NERC – North American Electric Reliability Corporation

NMI – Net metering & Interconnection

NYCHA – New York City Housing Authority

NYHOPS – New York Harbor Observation and Prediction System

NYISO – New York State Independent System Operator

NYSOEM – New York State Office of Emergency Management

OCEJ – New York City Mayor’s Office of Climate & Environmental Justice

OMB – Office of Management and Budget

OSHA – Occupational Health and Safety Administration

PUC – Public Utilities Commission

PV – Present value

RTO – Regional transmission organization

TOUR – time-of-use-rates

VDER – Value of Distributed Energy Resources

**Executive Summary**

Environmental justice (EJ) communities are disproportionately affected by power outages; the communities that face more frequent—and more severe—outages are often the ones with the fewest resources to address the problem (Collins, 2023). Of the communities that face power outages lasting over 8 hours, 40.4% of their population consists of racial and ethnic minorities on average (Do et. al., 2023).

Power outages can disrupt communication, travel, heating & cooling, and spoil food or medicines with potentially deadly consequences. Power outages are particularly disruptive for communities who lack access to alternative resources or backup generators. This analysis evaluates several policy alternatives based on the criteria of *equity improvements, environmental impact, administrative feasibility, and* cost. The alternatives are as follows:

Alternative 1: Let Present Trends Continue

Alternative 2: Battery Storage

Alternative 3: Upgrading Distribution Infrastructure

Alternative 4: Disaster Preparedness

This analysis recommends Alternative 2: Battery Storage. This alternative would facilitate the in-home installation of electrical batteries in EJ communities. In the event of power outages, households could use stored electricity to power essential systems and appliances. Battery installations have two additional positive effects even when there is not an outage. First, battery storage would facilitate future penetration of solar panels in EJ communities. Second, batteries can be used to reduce the cost-burden of electricity for households in EJ communities.

**Introduction**

Power outages are costly, inconvenient, and can be deadly. As global warming accelerates, extreme weather events become more common, and the United States’ electricity infrastructure continues to age, power outages will become more severe. Power outages also have significant equity implications because underserved communities are disproportionately impacted by the effects of power outages.

This analysis seeks to understand the impact of power outages on environmental justice (EJ) communities, assess the primary causes, and offer policy solutions to mitigate the worst effects of power outages.

**The Problem**

Problem Statement

Environmental justice (EJ) communities are disproportionately affected by power outages; the communities that face more frequent—and more severe—outages are often the ones with the fewest resources to address the problem (Collins, 2023). Of the communities that face power outages lasting over 8 hours, 40.4% of their population consists of racial and ethnic minorities on average (Do et. al., 2023).

Environmental Justice

Environmental justice (EJ)[[1]](#footnote-1) seeks to prevent and reverse the adverse and disproportionate effects of climate change (*What Is Environmental Justice?*, n.d.). The legacy of racism and other systematic barriers have prevented equitable access to clean and resilient environments for all people. This analysis defines an EJ community as:

A neighborhood or community, composed predominantly of persons of color or a substantial proportion of persons below the poverty line, that is subjected to a disproportionate burden of environmental hazards and/or experiences a significantly reduced quality of life relative to surrounding or comparative communities. (Environmental Justice Definitions, n.d.)

In addition to EJ communities being more likely to power outages and having fewer resources to mitigate the effects, they also face higher energy burdens which is associated with health and safety risks (Clarke et al., 2023). When a household pays more than 6% of their gross income for energy, it is considered an energy burden; low- and moderate-income households often have energy burdens exceeding 30% of annual income (Makhijani, 2021). Energy burdens have a disproportionate effect on EJ communities; Black households have energy burdens that are 64% higher than white households which exacerbates the effects of power outages (Clarke et al., 2023).

Effects of the Problem

Across the United States, power outages are occurring more frequently and lasting longer. The U.S. Energy Information Administration (EIA) found that in 2022, the average electricity customer in the U.S. was without power for over 6 hours and 18 minutes, up 57% from 2013 (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023).

Figure 1. Average duration of total annual electric power interruptions, United States (2013-2021) in hours per customer (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023)

A graph with blue bars

Description automatically generated

These power outages can have deadly consequences. In 2021, winter storm Uri swept through Texas and the Southwest leaving an estimated 4.5 million homes and businesses without power (The Winter Storm of 2021, n.d.). The Texas Department of Health and Human Services estimates that about 10% of the deaths caused by the storm were associated with power outages (Hellerstedt, 2021). But not all demographics face the same effects of power outages.

1. Medical Complications

The most immediate concerns associated with power outages are medical complications from electricity-dependent medical equipment (Casey et al., 2020). While the Occupational Safety and Health Administration (OSHA) requires hospitals to maintain backup generators and fuel storage, many people with electricity-dependent medical equipment do not have access to reliable backup generators (Electrical Generators in Hospitals, n.d.). In New York City, 7.6% of households use electric medical equipment (*How Power Outages Affect Health*, 2022).

Elderly populations are also particularly vulnerable to the effects of power outages. For example, nursing homes that lost power during Winter Storm Uri faced higher mortality rates than nursing homes that did not lose power (Skarh, 2021).

Some medications are also temperature sensitive such that sustained loss of power might cause early expiration. For example, some types of insulin and liquid antibiotics require refrigeration (“Safe Drug Use After a Natural Disaster,” 2019).

1. Food Insecurity

Blackouts cause electric appliances such as refrigerators to stop working which can cause perishable foods such as meat, dairy, and produce to spoil. The CDC advises that after four hours without power, meat and dairy in the refrigerator are unsafe to eat (Food Safety for Power Outages, n.d). EJ communities, where blackouts are more frequent, often have a lower median income and are disproportionally affected by the loss of healthy foods (Hunter-Adams, 2020). One result of frequent power outages is that people opt to purchase less healthy and more processed foods that do not perish during blackouts (Kern et al. 2017).

This issue is compounded by the fact that EJ communities often face existing food security challenges which are only exacerbated by power outages. In 2022, nearly 23% Black people in the U.S. faced insecurity (*Food Insecurity in Black Communities*, n.d.).

1. Lack of Heating and Cooling

As seen in Texas after winter storm Uri in 2021, grid outages left many people without heat (Farzan, 2021). It should be noted that in the case of Texas, natural gas supply problems also contributed to the lack of home heating. In New York City, electrification of home heating systems has been prioritized which would mean even more households might be affected by the sudden loss of power during winter months (ElectrifyNYC, n.d.).

1. Economic Impacts

In addition to the medical impacts of power outages, there are economic impacts of power outages as well. According to the U.S. Department of Energy (DOE), power outages cost over $150 billion to U.S. businesses each year. Much of the existing literature focuses on macroeconomic effects of grid outages (Economic Benefits of Increasing Electric Grid Resilience to Weather Outages, 2013), but households and individuals in EJ communities are disproportionately impacted.

1. Inequity

Researchers used a newly developed “Infrastructure Inequality Index” to categorize the severity of power outages by demographics (Coleman et al, 2023). They used real-time data from utility companies whose operations were affected by extreme weather during either winter storm Uri or hurricane Ida. They compared outage regions to spatial Gini Index data to understand demographic disparities in the length of outages experienced. They found that in extreme cases of power outages, lower income communities and communities with higher percentages of Hispanic residents had longer recovery periods after the extreme weather event. They also found evidence of social and spatial inequalities in the recovery periods from power outages. Coastal areas had less income inequality than areas inland that were affected. Texas and Louisiana were the two states primarily impacted by these extreme weather events but many factors including the state of infrastructure, types of extreme weather events, and energy generation mix are different in Texas or Louisiana than other regions of the U.S. While the findings might not be directly applicable to New York City, the Infrastructure Inequality index could be useful in assessing the equity impacts of various infrastructure upgrades.

Causes of the Problem

1. Climate Change

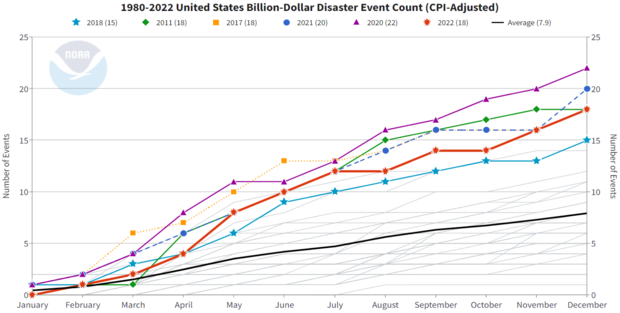
Earth’s average temperature has risen by about 2° Fahrenheit since 1850 and the rate of warming is increasing (Lindsey & Dahlman, 2024). Human activity since the industrial revolution is a leading cause of global warming (Climate Change 2021 – The Physical Science Basis, 2023).

Figure 2. Global average surface temperature (Lindsey & Dahlman, 2024)

A graph showing the growth of the year

Description automatically generated with medium confidence

One of the side effects of global warming is the increased likelihood and severity of extreme weather events such as heat waves, floods, droughts, hurricanes, and wildfires (*Extreme Weather*, n.d.). In 2023, the 5th warmest recorded year, the U.S. faced 28, a record number, of billion-dollar disasters (*U.S. Struck with Historic Number of Billion-Dollar Disasters in 2023*, 2024). 2023 is part of a larger trend which illustrations the increasing frequency and cost of extreme weather events.

Figure 3. Number of CPI-adjusted billion-dollar disasters in the U.S. (1980-2022) (Smith, 2023) 

Climate change and the increased frequency of extreme weather events are the most common causes of power outages. In the U.S., power outages were five times more likely when there was heavy rainfall, and fourteen times more likely under tropical storms or high winds (Do et. al., 2023). Outages due to weather related events are increasingly common.

Figure 4. Average duration of total annual electric power interruptions, United States (2013-2021) in hours per customer (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023)

A graph of blue and black bars

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Since 2013, the number of hours each electricity customer has without power has been growing over time. However, most of additional downtime is associated with major weather events. In 2021, there was 153% increase in the average number of hours without power and in 2022 there was a 78% increase compared to 2013 (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023).

1. Grid Infrastructure

While climate change exacerbates the problem, it is not the root cause of the disproportionate impacts that EJ communities face. Reliability problems in disadvantaged communities are sometimes caused by outdated or faulty grid infrastructure (Foster, 2024). Local distribution infrastructure is maintained by utility companies and regulated at the state level (Dennis, et. al., 2016). This infrastructure includes transformers that step down the voltage and local power lines (Delivery to consumers, n.d.).

Utility companies face an ongoing challenge of balancing governmental mandates, using their funds efficiently, and upgrading infrastructure at the right time. As energy efficiency and technology improves (Pentland, 2013), there is an incentive to wait instead of replacing existing infrastructure. This issue is further compounded by the fact that utility companies cannot—or do not want to—raise electricity rates on their most vulnerable consumers to pay for expensive infrastructure upgrades (Penn, 2023).

1. Lack of Preparedness:

Disadvantaged communities are more likely to suffer from a lack of disaster preparedness than wealthier communities. Even if both communities are without power for the same number of hours, on average, the EJ community faces additional challenges. Part of this disparity can be attributed to information asymmetries. EJ communities either do not have information about upcoming storms or they do not have the information about how to best prepare for those storms (Baxter, 2023). Language barriers in communicating with EJ communities are one of the systemic problems that contribute to a lack of preparation (Tai, 1999).

EJ communities often face systematic barriers. Some of these barriers are location dependent; many EJ communities live in less desirable or low-lying areas that might be more vulnerable to extreme weather or other causes of power outages (Do et. al., 2023). Areas that face storm surges require more preparation due to the extreme power of storm surges and the corrosive properties of seawater which further degrade the existing infrastructure (Anarde, et. al., 2017).

Evaluating the Severity of Power Outages

Mitigating the worst effects of power outages requires comprehensive evaluation of the frequency and severity of power outages to map the problem and to evaluate potential salutations. There are several different metrics and methods used to analyze power outages.

1. Frequency and Length of Power Outages

The EIA publishes monthly data on power outages in their Electric Power Monthly report (Electrical Power Monthly, n.d.). Part of the report is dedicated to the frequency of power outages at the state level. The report also includes data on the length of each outage in hours. These objective metrics can also be used to classify outages based on their duration.

1. Communities Impacted

To better understand who is impacted by power outages, it is necessary to use data on power outages is at the county level. Using this data in addition to census data, researchers can identify the demographics of communities that are affected by power outages (Do et. al., 2023).

1. Number of Households Impacted

A third method of evaluating the impact of power outages is to multiply the number of households affected by a power outage by the number of hours that power was out for. This method also uses a combination of EIA and Census data. One limitation is that this metric can underestimate the severity of long power outages for a small population compared to a minor outage that affects a lot of people (Do et. al., 2023).

**Government Involvement**

There are several government agencies that play an important role in regulating utilities and providing funding for infrastructure improvements.

At the federal level, the Federal Energy Regulatory Commission (FERC) is the primary regulator of interstate electricity transmission, prices, and reliability under the Federal Power Act (What FERC Does, n.d.). FERC is an independent regulatory commission whose commissioners are appointed by the President and confirmed by Congress. FERC’s actions are also overseen by Congress, specifically the Energy and Commerce Committee. Since FERC’s jurisdiction is related to interstate energy transmission, their role varies across the country. For example, FERC has extremely limited jurisdiction in Texas where most of the electric grid is intrastate (ERCOT, n.d.). FERC also oversees the North American Electric Reliability Corporation (NERC) who work across Canada, the U.S., and Mexico to coordinate energy management (Reliability Guideline Natural Gas and Electrical Operational Coordination Considerations, n.d.).

The Environmental Protection Agency (EPA) is also involved with electricity generation and transmission via NEPA and the Clean Air Act (Clean Air Act Standards for Electric Utilities, n.d.). The DOE’snf Loan Programs Office (LPO) helps finance projects that promote clean energy and reliability (Loan Programs Office, n.d.).

At the state level, public utilities commissions (PUCs) are the primary regulators. Each state has their own PUC although names for those regulatory bodies vary by state (An Overview of PUC s for State Environment and Energy Officials, 2010). The primary responsibility of PUCs is to ensure that utility companies are providing effective electricity at “just and reasonable” prices (An Overview of PUC s for State Environment and Energy Officials, 2010).

**Current Regulatory Landscape in New York**

Selling Electricity Back to the Grid

When an electric utility customer generates or stores more electricity than they use, some utilities provide a service where the customer can sell that electricity back to the grid. Net metering is how New York, and many other grids handle these transactions. Instead of the utility company paying for each megawatt hour (MWh) supplied back to the grid, they give customers a credit on their electricity bill (*NYS Net Metering FAQ - Residential*, n.d.). These credits can vary depending on state regulations (Pickerel, 2020). Currently, New York is transitioning away from its net metering policy to the Value of Distributed Energy Resources (VDER) or Value Stack. The VDER model takes into account a number of factors including environmental impact, reduced demand, location, energy value, and capacity value (*The Value Stack - Value of Distributed Energy Resources*, n.d.). The VDER policy will likely improve the feasibility of this program because these batteries will be placed in areas that disproportionally face power outages and will create opportunity for additional solar panel installations.

Vegetation Management Around Powerlines

Since trees knocking down—or coming into contact with—powerlines is a common cause of outages, New York State requires that utility companies who own and operate power lines submit plans to the PUC regarding vegetation management around power lines (*Tree Trimming and Vegetation Management*, n.d.).

**Policy Alternatives for Mitigating the Effects of Power Outages**

Status Quo

This alternative would allow for present trends to continue. These trends include worsening climate change, aging infrastructure, and many disadvantaged communities continuing to be underserved. States will continue with their own resilience initiatives as well as routine maintenance of existing infrastructure.

The DOE has programs to improve grid resilience and modernize the electrical grid. In 2023, the DOE announced they would be providing $3.5 billion to 44 states for the purpose of improving grid resiliency (*What Does It Take to Modernize the U.S. Electric Grid?*, 2023). Historically, EJ have been underserved and the DOE’s plan does not explicitly focus on existing disadvantaged communities.

Battery Storage

1. Summary

To best mitigate the effects of power outages in EJ communities, this alternative would provide funding for small and large batteries (“Powerwall”, n.d. & “Utility-Scale Battery Storage”, n.d.). Small battery units would be installed in single family homes and large batteries would be installed in large multifamily apartment buildings.

In the event of a power outage, these battery systems would be able to supply electricity for 2-10 hours depending on the size and type of battery used (“Utility-Scale Battery Storage”, n.d.). Since power outages are relatively infrequent, these batteries can also be used during times of high reliability to save money on a day-to-day basis when no power outage is imminent. This is effective because power outages are almost exclusively causes by severe weather which can be reliably tracked (“Electric Service Reliability Report 2022”, n.d.).

1. Literature

As of 2022, the U.S. had about 8.8 gigawatts (GW) or 8.8 billion watts of utility-scale battery storage across more than 400 facilities (Energy storage for electricity generation, n.d.). Battery storage at both the utility scale and household level have both been shown to improve reliability. Johnson et. al. researched the effects of different utility scale energy storage methods based on cost and reliability improvements in Texas (2021). They found that despite Compressed Air Energy Storage (CAES) being the most effective method of reducing the estimated price of inertia, the income generated from them was found to not be enough to motivate widespread adoption at grid-scale. CAES was also most effective when 51% or more the energy generation mix was from renewable sources. Overall, energy storage built near renewable-rich areas or near critical transmission pathways had the most economic impact. One limit to the external validity of this study is that Texas is uniquely situated in terms of the large role that wind-generation plays and in terms of the efficiency of solar panels in the southwestern United States (Texas’ Electricity Resources, n.d.).

Large scale battery storage has been one method of improving reliability, but access to smaller-scale, local storage can also have major effects. For several years, a utility company in Vermont has leased out batteries to their customers to improve reliability during short power outages. The same utility company has submitted a proposal to Vermont’s PUC to install batteries for every customer (Penn, 2023).

Electricity prices are not constant, they vary depending on demand which is called time-of-use-rates (TOUR). This means that electricity prices are lower at night. For example, Con-Edison, a utility company in New York offers a TOUR that charges 33.05 centers per KWh from 8am-12am but only 2.33 centers per KWh outside of those hours (“Time-Of-Use-Rates | Con Edison, n.d.).

1. Implementation Plan

Depending on the state, implementing battery storage might first require coordination with the PUC and local utility company. Under this alternative, batteries would be used at the household or building level and would sell power back to the utilities when prices are higher. Some states have interconnection requirements and approvals, especially when selling energy back to the grid (*Will I Need a Permit to Install a Battery?*, 2019). In New York, there is a Net Metering & Interconnection (NMI) Working Group that includes all major electric utility companies in New York (*NYS Net Metering FAQ - Residential*, n.d.).. This group, supported by the DOE has facilitated net metering across New York and will make implementing this alternative much more feasible. An additional consideration for the implementation plan is that to sell power back to the grid, inverters[[2]](#footnote-2) and batteries will need to be installed.

The next step for implementation would be identifying buildings in EJ communities that would benefit the most from battery installations. The New York City Housing Authority (NYCHA) has developed plans to install solar panels and battery storage on several buildings (*NYCHA Press Release*, 2023). Partnering with NYCHA would allow for effective implementation since they have experience installing this type of infrastructure already.

In addition to coordinating with NYCHA to begin this program, public private partnerships might be a cost-effective option to improve reliability. If a company fronts the cost of battery installation and handles maintenance costs, they would receive a share of the profits when electricity is sold back to the grid.

To be most effective, the installed batteries should only be used to power the most essential appliances such as refrigerators, freezers, medical equipment, or charging a phone for emergency reasons. Limiting the use of batteries to essential needs would allow for more effective use during long power outages. However, in existing buildings, it is extremely difficult to limit the use of batteries for only those purposes. It is impossible to isolate only those essential circuits during emergencies. In new construction, it would be possible to build in an “emergency dedicated outlet” that is hooked up to a battery. There are four potential strategies to extend the use of batteries. The simplest but least reliable is to encourage residents to conserve electricity during power outages. This would require turning off lights, unplugging other appliances, and being very careful about how electricity is used. The next way would be to dramatically increase battery storage to supply all electricity demands. The third solution would be to only supply a select number of apartments which have the greatest need. The final and most difficult way would be to re-wire building to add “emergency dedicated outlets” that are backed up by battery storage.

For the purposes of this analysis, this alternative will install 4,800 batteries in households based on the scale of a similar program in Vermont (*GMP’s Request to Expand Customer Access to Cost-Effective Home Energy Storage Through Popular Powerwall and BYOD Battery Programs Is Approved*, 2023).

Upgrading Distribution Infrastructure

1. Summary

Usually, power outages are not caused because of a lack of generation capacity but because there are disruptions when it comes to getting that electricity to consumers. Local distribution infrastructure such as neighborhood powerlines and small transformers are the most common direct cause of power outages. This alternative would provide funding and direct state regulators to focus on resiliency measures in EJ communities.

1. Literature

In addition to reliability improvements, building additional transmission between utility scale renewable energy generation and urban demand hubs was associated with a reduction in pollution (Fell et. al., 2021). Since many EJ communities are located within urban centers with high electricity demand, increasing transmission infrastructure would specifically improve outcomes for those communities. However, this approach has major limitations. In terms of practicality, building large scale transmission is expensive and difficult given the current regulatory landscape (Klass et. al, 2012).

Interstate transmission lines are subject to regulation from FERC as well as each state’s PUC that the transmission lines cross into. In addition to challenges from regulators, there has been significant pushback from advocacy groups and local governments (Popovitch & Plumber, 2023). Local residents and government officials often block transmission line construction projects because of the unpopular–but necessary–use of eminent domain. Local opposition often comes in the form of advocacy groups that pursue lengthy litigation efforts to block transmission projects under the National Environmental Policy Act (NEPA), the Clean Air & Water Acts, or the Endangered Species Act (Popovitch & Plumber, 2023).  The process is further complicated when proposed transmission lines cross critical habitats, tribal lands, or national parks. As a result, the International Energy Agency (IEA) estimates that new transmission projects in the United States take upwards of a decade to complete when factoring in planning, permitting, and construction (Average lead times to build new electricity grid assets in Europe and the United States, n.d.). The difficulties with constructing high-voltage electrical transmission lines is further compounded by the cost; it is estimated that long-distance electrical lines are eleven times more expensive to build than natural gas pipelines and over 20 times more expensive to build than other liquid fuel pipelines (DeSantis et. al., 2021).

Local distribution is often the first failure point during grid outages with aging substations, transformers, or power lines being especially vulnerable (Specht, 2020). This type of outage affects the smallest number of people, but often, EJ communities face disproportionate effects. Bolstering distribution infrastructure is a targeted way to improve reliability for specific communities.

The first strategy is to “underground” or bury local distribution lines to prevent high winds and fallen tree limbs from interrupting electricity transmission. While undergrounding power lines improves reliable, it is often too expensive to justify (Mara, n.d.). However, under certain circumstances, undergrounding powerlines can be cost-effective. The factors that made undergrounding power lines the most effective was decreasing the discount rate, many customers using an underground line, lower replacement cost of underground lines, and shorter overhead line life spans (Larson, 2016). Several of these conditions would indicate that undergrounded powerlines in EJ communities would be cost effective. Since EJ communities are often in population-dense urban settings with deteriorating overhead lines, submerged power lines might be more beneficial than in many other scenarios. One major limitation of this study is that it used a national reliability model for electric utilities which may not be applicable to the type of local distribution upgrades needed in EJ communities. Additionally, the analysis makes assumptions based on the current state of prices, labor markets, and easement use which may have changed in the last eight years.

A second strategy is to improve pre-storm maintenance to reduce changes of outages. Ice collecting on power lines and trees falling or touching power lines are two of the most common issues with local distribution (Fan et. al., 2023).

1. Implementation Plan:

The state PUC would be tasked with identifying EJ communities that would benefit the most from new or upgraded distribution infrastructure. The state PUC works with utility providers to develop plans. Ultimately, local utility providers such as Con Edison would be the ones to build and maintain infrastructure projects. The local utility companies would work with the PUC and local governments to plan new distribution lines, identify the most vulnerable power lines to bury, and build out additional redundancy.

Disaster Preparedness

1. Summary

This alternative would provide three levels of preparedness for power outages in EJ communities. The first is informational. State and local governments would disseminate information about when power outages might occur and how to prepare. The second level is equipping community centers with climate-controlled backup systems. The third would be direct aid to disadvantaged communities.

1. Literature

EJ communities often lack information about upcoming storms, or they do not have the information about how to best prepare for those storms (Baxter, 2023). Language barriers in communicating with EJ communities are one of the systemic problems that contribute to a lack of preparation (Tai, 1999). New York City’s Office of Emergency Management (OEM) has worked to mitigate these challenges through various social media and informational initiatives. On their website they have a disaster preparation podcast, emergency phone lines, and advanced warning systems (*Stay Informed - Community Preparedness*, n.d.). These resources are also available in multiple languages. For example, NYC’s advanced warning system “Notify NYC” is available in 14 languages[[3]](#footnote-3) and is available through different avenues including email, text, or phone call (Messaging Toolkit from NYC Emergency Management, n.d.). However, people need to opt into the system and many people may not know the existing resources.

In New York City, 42% of households reported that that they did not have adequate preparation for a power outage (*How Power Outages Affect Health*, 2022). Adequate preparation was defined as a working flashlight and a 3-day supply of both food and water for each person in the household (*How Power Outages Affect Health*, 2022). According to the Federal Emergency Management Agency (FEMA), in addition to non-perishable food and water, households that have additional electricity dependent medical devices should have a backup source of power or plan in place (*Prepare Yourself for a Power Outage*, 2022). Dry ice can also be used to preserve food in refrigerators or freezers for more time (*Power Outages: Keep Food Safe*, n.d.). 50 pounds of dry ice will preserve food in a 20 cubic foot refrigerator for four days (*Power Outages: Keep Food Safe*, n.d.).

According to FEMA, Community Resiliency refers to “the ability of a community to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions” (*Community Resilience*, n.d.). The New York City Mayor’s Office of Climate & Environmental Justice (OCEJ) works with communities to better equip them in case of disasters (*Community Resiliency*, n.d.). Historically underserved communities have not had the necessary resources to build Community Resiliency capacity. Some of OCEJ’s initiatives in EJ communities have included training classes, information sharing, and connecting community networks to NYC’s Emergency Operations Center during disasters (*Community Resiliency*, n.d.).

New York City has designated disaster shelters across the city which have traditionally been used as evacuation centers during hurricanes or flooding (Ready New York, n.d.). One advantage of disaster shelters is that they allow for easier delivery of essential supplies as opposed to delivering supplies to dozens or hundreds of households. Disaster shelters can also be used as disaster preparedness hubs in the event of power outages. Resources such as dry ice and non-perishable foods could be delivered to community centers in EJ communities where they could be further distributed to residents. It is also easier to outfit a handful of community centers with backup generators which would allow for heating, ventilation, and air conditioning (HVAC) systems to operate in otherwise dangerous weather conditions.

1. Implementation Plan:

In New York, there are existing government agencies that handle disaster preparedness. The New York State Office of Emergency Management (OEM) and the FEMA already have plans and procedures in place when responding to electricity outages and extreme weather (“Electric Service Reliability Report 2022”, n.d.). These agencies would be the most equipped to expand disaster relief during power outages. OEM also has existing channels of communication with electric utility companies in New York which will facilitate coordination regarding the length, severity, and location of power outages (*Plan for Hazards - Utility Disruptions*, n.d.).

It would likely be too difficult for OEM to create a maintain a database of all households that were eligible for disaster assistance. Instead, it would be more feasible to identify community centers that could distribute supplies as needed. Supplies including dry ice to preserve perishable foods, medicines, and flashlights would be more readily available to those who need it. Implementing the policy at this level would also allow for greater community input with regards to the type of supplies needed and how they would be best distributed.

An optional component would be to outfit those community centers with backup diesel generators that could supply power for EJ communities. This would create climate-controlled spaces in case temperatures reached dangerous levels. This component would face additional challenges with respect to pushback against greater reliance on fossil-fuels and the need to have diesel fuel stored at each community center location.

For the purposes of this analysis, this alternative will supply 30 community centers in EJ communities with the resources to assist at least 100 families with supplies.

**Rejected Policy Alternatives**

Micro-grids

Micro-grids are self-sufficient, localized power grids that have electricity generation capacity and energy storage capacity. Most frequently, micro-grids rely on solar panels to generate power and batteries to store that electricity for times when the sunlight access is limited (Microgrids, n.d.). Micro-grids can continue to run even if there are outages in other parts of the grid. Currently, microgrids only make up less than .03% of all electricity generation capacity in the U.S. (*Microgrids - Technology Solutions*, n.d.). However, microgrid capacity has increased by nearly 11% in since 2020 in response to growing demand for renewable sources and to prevent outages due to natural disasters (*Microgrids - Technology Solutions*, n.d.).

Microgrids have been most successful in rural areas and small islands where it is extremely expensive to build out traditional transmission infrastructure (*Microgrids Can Help Sub-Saharan Africa Achieve Universal Energy Access*, n.d.). In Sub-Saharan Africa it is estimated that 600 million people lack access to modern electrical services and it is too expensive to build out traditional transmission infrastructure to many remote villages (*Microgrids Can Help Sub-Saharan Africa Achieve Universal Energy Access*, n.d.). Microgrids have been a method used to supply many villages in Africa with electricity without the expensive infrastructure that was previously required.

Microgrids can be independent, connected to the grid, or connected to other microgrids. Gao et. al. (2019) found that different energy management systems (EMS) can be used to increase microgrid reliability which would further mitigate the effects of power outages. They modeled networked microgrids to investigate how to mitigate the effect of high probability but low impact outages while minimizing the amount of load shed required to maintain grid operations. They found that use of EMS can improve reliability but at a cost of more rapid degradation of the batteries used. One issue with this study is that the researchers were unable to observe load data and so they had to model the data for their calculations. While their validity tests returned expected results, microgrids simply have not been deployed widely enough to observe effects in the field yet.

There are notable challenges and benefits associated with the implementation of microgrids in urban settings. Specifically direct current (DC) microgrids offer benefits to urban locations without the challenges associated with alternating current (AC) microgrids such as synchronization, reactive power control, and frequency control (Rangarajan et. al., 2023). But DC microgrids are not without limitations. One main limitation is that because of limits to current battery technology, they rely heavily on physical inertia, such as large, rotating flywheels. The most important challenge with microgrids is that they must have enough generation capacity to be self-sufficient. Solar panels and wind turbines require lots of land area which is impossible in dense urban areas. The average NYCHA building has 76 apartments; each building would require up to 10 football fields worth of space for solar panels (Appendix A). The space needed for renewable energy generation is too great in dense urban areas. The only way that microgrids could function is with either natural gas generators or small-nuclear reactors for each building which is also infeasible.

Energy Efficiency Improvements

One approach to bolstering reliability is to reduce electricity demand through energy efficiency upgrades. If electrical appliances use less electricity, they are less likely to overload the grid when transmission is reduced. Energy efficiency improvements have the greatest reliability impact during heat waves when many people use more electricity for air conditioning (Naoshin, 2023).

Researchers studying the effect of energy efficiency upgrades found that households with energy efficient lightbulbs had a significant effect on household electricity usage (Carranza & Meeks, 2016). They found that the effect, when aggregated across households, reduced the number of days with power outages. However, this study was conducted outside of the United States and the findings may not be directly applicable. Another issue with validity was that because of the researcher’s limited budget, several households in the control group were never surveyed in addition to 10% of households whose residents moved during the study.

While energy efficiency programs are extremely environmentally beneficial and reduce overall electricity demand, they are unlikely to prevent outages during extreme weather events. Power outages are usually caused by extreme weather events which disrupt transmission instead of generation. While energy efficiency improvements would reduce the risk of power outages during heat waves, they provide little protection for the numerous other causes of outages.

**Evaluative Criteria**

Equity

The slogan “nothing about us without us” has been used by advocacy groups seeking equal opportunities and participation about matters that affect them (*International Day of Disabled Persons*, 2004). This slogan is important for EJ as well. Any policies aimed at promoting equity for EJ communities should include the full participation of those impacted at the local level.

Each policy alternative will be assessed in terms of how effectively it mitigates the existing inequities from power outages. This criterion will evaluate how well the alternative mitigates the effects of power outages for EJ communities. It will also consider how easily the alternative could be used to target specific EJ communities as opposed to general reliability benefits that do not address inequity directly. The outcome of each alternative will be ranked on a scale of “High”, “Medium”, or “Low” depending on its effectiveness.

High – A “High” equity ranking is given to alternatives that can easily be directly targeted towards EJ communities, reduce the burdens of power outages, and will mitigate disparities over time.

Medium – A “Medium” equity ranking is given to alternatives that can possibly be targeted towards EJ communities, reduce the burdens of power outages, and will not exacerbate disparities over time.

Low – A “Low” equity ranking is given to alternatives that does not target EJ communities or reduce disparities but might reduce the burdens of power outages.

Environmental Impact

Long-term environmental impacts must be considered when making any changes to the electrical grid. The benefits of improved reliability should be weighed against the environmental outcomes that also disproportionately affect EJ communities. For example, installing diesel- or gasoline-powered backup generators in every home may address the problem but it comes with additional environmental costs. The outcome of each alternative will be ranked on a scale of “High”, “Medium”, or “Low” depending on its environmental impact.

High – A “High” environmental impact ranking means that the alternative will likely result in greater net GHG emissions.

Medium – A “Medium” environmental impact ranking means that the alternative might result in greater net GHG emissions.

Low – A “Low” environmental impact ranking means that the alternative will likely reduce net GHG emissions.

Administrative Feasibility

State PUCs have competing priorities including infrastructure maintenance, reliability upgrades, and renewable energy projects. The ultimate recommendation should be something that can reasonably be implemented at the state and local levels. Infrastructure projects must be cited at the local level which might face political or public opposition. The recommendation should consider the community impacts as well. Administrative feasibility will also consider if the alternative has been implemented before and how likely it would work again in urban, EJ communities. The outcome of each alternative will be ranked on a scale of “High”, “Medium”, or “Low” depending on its feasibility.

High – A “High” administrative feasibility ranking means that a similar policy has been successfully implemented in New York City or has a high likelihood of success.

Medium – A “Medium” administrative feasibility ranking means that while there have been similar policies or initiatives that have been successfully implemented, there are potential regulatory, political, or legal barriers that could prevent successful implementation.

Low – A “Low” administrative feasibility ranking means that there are substantial existing regulatory, political, legal, or other barriers to implementation.

Cost

The cost of each alternative is important because EJ already bear significant energy burdens and increasing electricity prices would exacerbate existing energy burdens. Additionally, money spent on bolstering the electrical reliability of EJ communities has tradeoffs that could support those communities in other ways.

All costs will be reported in present value (PV) of the lifespan of the alternative. For example, if one alternative is a program that lasts for 10 years, it’s costs will be reported as the PV of the program over its lifespan. PVs are calculated using the 2% discount rate recommended by the White House’s Office of Management and Budget (OMB) (*Biden-Harris Administration Releases Final Guidance to Improve Regulatory Analysis*, 2023). This discount rate reflects a greater value given to the long-term implications of policy decision. However, the cost calculations in the appendix and the reported totals in the outcomes matrix are given as a range using both 2% and 7% discount rates.

The evaluation of costs will also include a qualitative description of the expected benefits associated with each alternative.

**Evaluation of Alternatives**

Alternative: Status Quo

1. Equity

The status quo has a low equity ranking because EJ communities are disproportionately impacted by power outages (Do et. al., 2023). The worsening effects of climate change will continue to exacerbate this disparity (Collins, 2023). Not only are EJ communities more likely to be impacted than other communities, but they also lack the resources to move or to mitigate the worst effects of climate change.

1. Environmental Impact

If present trends continue, the status quo will have a medium negative environmental impact. The status quo contributes to greenhouse gas (GHG) emissions because residents impacted by power outages have to travel more for food and other critical resources. Power outages lead to wasted food, more demand for medical equipment, and other waste which can degrade the environment.

1. Administrative Feasibility

Letting present trends continue has high administrative feasibility because there is no additional effort needed from government agencies. There are several ways in which administrative feasibility might be impacted under the status quo. First, there is potential for public opinion might shift. There is also a chance that the cost of providing current services (infrastructure maintenance, disaster preparedness etc.) increases as infrastructure ages.

1. Cost

There are costs associated with fixing problems as they arise as opposed to preventative measures. These costs include replacing transmission lines, cost of maintenance, as well as lost tax revenue from business disruptions. These costs are especially prominent during extreme weather events such as hurricane Sandy. The cost of replacing electricity grid infrastructure after hurricane Sandy was over $60 million (See Appendix A). There are other costs associated with maintaining the current electrical grid, but those costs would still be paid in each of the other alternatives, so this analysis does not add those costs to the overall total. After discounting the PV of this cost is $39.6 million.

Alternative: Battery Storage

1. Equity

This alternative ranks high in terms of equity because it would directly improve reliability in low-income areas. It would be implemented such that batteries are placed in households or building that would not have been able to afford the high up-front costs. Not only does it bolster reliability, but it also has the potential to generate income in EJ communities and reduces electricity bills.

1. Environmental Impact

This alternative has positive environmental impacts since batteries can purchase cheap, renewable energy and reduce demand for fossil-fuel fired generation. When electricity demand is at its highest points,[[4]](#footnote-4) utility companies need to be able to create more supply to keep up. Utility companies use fossil-fuel powered “peaker plants” to ramp up production during these times (McNamara, 2020). With enough energy storage, the demand for peaker plants could be reduced by evening out electricity demand. This would make renewable generation more efficient and reduce fossil-fuel emissions in the power sector which would improve the environmental impact of this alternative.

1. Administrative Feasibility

Installing battery storage has moderate administrative feasibility because while the scale of this project would be larger than existing projects, there are proven models for implementation. The New York State Energy Research and Development Authority (NYSERDA) has already worked with private companies to install small scale batteries (“NY Apartment Building Provides Grid Management Services with Installation of Battery, Software,” 2021). Outside of New York, utility companies are interested in battery storage installation because of the energy management flexibility and cost savings independent from the reliability benefits (Spector, 2023).

1. Cost

Installing battery storage capacity in households has several benefits including reliability improvements, environmental benefits, and the potential to lower the cost of electricity for those households. However, battery storage requires steep up-front costs that can be difficult for many families in EJ communities. A single battery can range from $10,000 to $20,000 (Moore & Tynan, 2024). For the purposes of this analysis, we will use the upper bound of the battery price to include maintenance and installation costs. Based on this, it would cost $96 million initially to install the 4,800 batteries for this alternative. The utility company Green Mountain Power in Vermont estimates that each year, 4,800 batteries save $3 million in reduced energy costs which could be passed onto the consumer (*GMP’s Request to Expand Customer Access to Cost-Effective Home Energy Storage Through Popular Powerwall and BYOD Battery Programs Is Approved*, 2023). The total estimated costs for this alternative have a PV of $56.33 million.

If the cost savings were passed on to the consumer directly, it would dramatically lower the tax burden for households in EJ communities. It could save up to 66.7% of a household’s electricity bill each month (Appendix C). Even if 50% of the profits were shared through a public-private partnership, it could still reduce electricity bills by over 30% while bolstering reliability.

Alternative: Electricity Distribution Infrastructure

1. Equity

Upgrading electrical distribution infrastructure in EJ communities will moderately improve equity. This alternative would re-invest in communities that have been disproportionately underserved in terms of infrastructure projects. However, there are technical limitations to how and where distribution infrastructure can be buried or installed, especially in urban areas (Gold, 2023). These means the equity improvements will vary by community. Upgrading distribution infrastructure also has the potential to increase electricity bills for customers in EJ communities.

1. Environmental Impact

Bolstering reliability through improving distribution infrastructure will have a moderate environmental impact because there are both positive and negative effects. One of the positive environmental impacts is that this alternative can allow for more integration of renewable energy depending on how and where transmission infrastructure is built (Brockway et al., 2021). This alternative also requires some negative environmental impacts such as disruptions during installation, cutting down trees and foliage for new lines, and cutting down trees around existing lines (*Tree Care*, n.d.)

1. Administrative Feasibility

Despite distribution infrastructure upgrades being commonplace, this alternative is ranked as having low administrative feasibility because there are a number of challenges associated with it. First, state public utility commissions and utility companies have a lot of influence over how and when distribution or transmission infrastructure is changed. Second, installation of new lines can be disruptive and expensive. Third, there is large potential for conflicts between state, local, and federal regulators and officials in terms of citing and construction.

1. Cost

Upgrading distribution infrastructure has several benefits including reliability improvements and modernized infrastructure that can better adapt to a growing share of renewable generation. However, upgrading distribution is extremely expensive and requires maintenance. Currently, New York City has about 37,000 miles of overhead distribution lines and 94,000 miles of underground distribution lines (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). Many utility companies have prioritized undergrounding lines in advantaged communities, so the more vulnerable overhead distribution lines are disproportionately located in EJ communities. If utility companies were to underground just 5% of the overhead distribution lines, it would cost an estimated $7.4 billion in upfront construction costs (Appendix D). This cost would be even more expensive if it was determined that new distribution infrastructure was required. Even considering the lowest end of maintenance and operation costs over a 40-year expected lifespan, this alternative would be the most expensive with a PV of $7.46 billion (Overhead Vs. Underground Fact Sheet, n.d.) (Appendix D).

Alternative: Disaster Preparedness

1. Equity

Disaster preparedness has a moderate equity ranking. While it does mitigate the worst effects of power outages for EJ communities, it does not solve any of the underlying problems. It is a temporary solution that will likely ease suffering in the short term, but prevention efforts would be more equitable in the long term.

1. Environmental Impact

This alternative has a high environmental impact rating because of the environmental costs associated with suppling disaster preparedness. First, it requires increased transportation to deliver supplies both in terms of sourcing supplies from areas that were not affected by the outages and in terms of local distribution of those supplies. The environmental impact from increased transportation comes primarily from vehicle emissions. This impact can be mitigated over time by using electric vehicles or drones, but traditional trucking is currently the most reliable method of local transportation (*Provide Transportation Services*, 2024). Second, increased distribution of disposable items has environmental impacts. Finally, if there is increased use of diesel generators in community centers, there are potential localized air quality issues (Gilmore et al., 2006). Those generators also increase demand for GHG emitting fuels.

1. Administrative Feasibility

Disaster preparedness have a moderate administrative feasibility ranking. There are existing federal, state, and local disaster response plans and agencies which could facilitate the new measures in this alternative. In particular, NYSEM and FEMA already have disaster response programs and would be the primary coordinators of this alternative (“Electric Service Reliability Report 2022”, n.d.). This alternative would include a relatively small expansion of deliveries to a limited number of locations but it still additional agency workload. The largest hurdle is likely to be diesel generators due to political concerns and various carbon-reduction initiatives. For example, to make this policy more administratively feasible there might have to be payments for carbon offsets.

Informational campaigns are also important for disaster preparedness. Under this alternative, agencies would also produce materials to better inform people how to prepare for power outages and how to access the supplies this alternative would provide.

1. Cost

Disaster preparedness has several key benefits including more symmetrical information access and expanded access to food, water, medicines, and climate-controlled environments during disasters. The costs associated with these benefits include information campaigns, disaster supplies, generators, and associated administrative costs. The evaluations for this alternative assume that 30 community centers in EJ communities would be equipped to supply at least 100 households for the next decade. The estimated cost of this alternative has a PV of $248.5 million (Appendix E).

**Outcomes Matrix**

Table 1. Evaluated Outcomes by Policy Option

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Status Quo | Disaster Preparedness | Distribution Infrastructure | Battery Storage |
| Equity | Low | Medium | Medium | High |
| Environmental Impact | Medium | High | Medium | Low |
| Administrative Feasibility | High | Medium | Low | Medium |
| Cost  (Range based on 2% and 7% discount rates) | $14.49 – $39.59 million | $236.4 – $248.5 million | $7.01 – $7.46 billion | $56.36 – $64.18 million |

**Recommendation**

It is my final recommendation that battery storage through public-private partnerships be implemented. They ensure residents have electricity in times of power outages, they generate income during regular use, and they allow for greater penetration of renewable energy sources. This solution would directly benefit EJ communities because it would provide greater reliability while also potentially saving money for the most vulnerable customers. Where rooftop solar is not possible, the environment and the electrical grid would still benefit from storage that mitigates the variance in renewable generation. This alternative is already more administratively feasible because there are model communities where similar programs have been implemented and New York has already undertaken some similar projects at smaller scales.

This alternative is the most likely to be successful because it focuses on long-term prevention in a cost-effective way. While disaster preparedness might be the most direct way to solve the immediate effects of power outages in the short term, it does little to address the underlying inequitable distribution of electrical grid infrastructure.

Battery storage technology has also improved dramatically over the past decade and will likely continue to improve as EVs and renewable energy sources become more prominent (Crownhart, 2023). These improvements have led to reduced costs and better batteries (Vinkhuyzen, 2023). These technological advancements have dramatically improved the viability of this alternative. Furthermore, given that the lifespan of current battery technology is about 10-20 years, implementing this policy could facilitate upgrading the battery storage as technology improves (Gitlin, 2023).

Battery storage also has positive effects beyond reliability improvements because it would make implementing distributed solar generation more feasible in many places. In fact, the push for more battery storage in New York has been a result of greater solar penetration but the inverse is also possible. Once battery storage is installed, it will boost the effectiveness of future solar panel equipment which might incentivize future adoption of renewable energy sources.

**Conclusion**

This analysis finds that putting battery storage in households is the best way to mitigate the effect of power outages in EJ communities. It is an effective and low-cost approach that creates ancillary benefits such as reduced electricity bills and potential for the expansion of renewable energy. While traditional microgrids can also be effective in rural areas, the urban settings of many EJ communities do not provide enough space for solar panels or other generation resources.

Power outages disproportionately impact EJ communities, and the issue will only be exacerbated with the acceleration of global warming. EJ communities have historically been underserved and the aging distribution infrastructure will lead to more inequity over time. While disaster preparedness might ameliorate the immediate effects, it will not address the growing underlying inequities. Access to food, medicine, and living climates are all threatened by extended power outages. As extreme weather events threaten grid reliability, battery storage will boost resilience for communities.

**Appendix A: Microgrid Space Estimates**

|  |  |
| --- | --- |
| Facts/Assumptions | Calculation |
| NYCHA has 161,585 public housing apartments in 2,103 residential buildings (*NYCHA 2023 Fact Sheet*, 2023) | Average number of apartments per building:  161,585/2,103 = 76.84 |
| The average 1-2 bedroom apartment uses 20-30KWh of electricity per day (*What’s the Average Electricity Bill of a 1 & 2 Bedroom Apartment?*, 2022) | Electricity need for the average NYCHA building: 76.84 \* 20 = 1536.8KWh |
| Unit Conversion KWh to MWh | 1536KWh = 1.536 MWh |
| 8.5 Acres of land are needed to supply 1MW of solar electricity generation (*Solar Energy*, n.d.) | 1.536MW \* 8.5 = 13.056 acres |
| A football field is 1.32 acres (*How Big Is a Football Field?*, 2022) | 13.056 / 1.32 = ~10 Football Fields of solar panels to power each NYCHA building on average |

**Appendix B: Status Quo Costs**

|  |  |
| --- | --- |
| Facts/Assumptions | Cost |
| Replacement transmission (cost per mile) (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). | Overhead transmission: $930,000 - $7.2mm  Underground transmission: $3.6mm - $23.7mm  Overhead distribution: $430,000 - $3.6mm  Underground distribution: $3.6mm - $7.3mm |
| Hurricane Sandy Electrical Grid Damage (*Hurricane Sandy Event Analysis Report*, 2014) | 140 miles of transmission went down  900 transformers failed/damaged/went offline |
| Cost Estimate | Most conservative estimate: 140 \* $430,000 = $60.2mm |
| Average Yearly Cost if a Hurricane Sandy level storm occurs ever 10 years | 60.2 mm /10 = 6 mm /year on average (Lin et al., 2016) |
| Average Yearly Cost if a Hurricane Sandy level storm occurs ever 20 years | 60.2 mm /20 = 3 mm /year on average (Lin et al., 2016) |
| PV of cost with a discount rate of 2% | $39,586,549.01 |
| PV of cost with a discount rate of 7% | $14,490,785.20 |

**Appendix C: Battery Storage Costs**

|  |  |
| --- | --- |
| Facts/Assumptions | Cost |
| Residential battery costs | $10,000 - $20,000 for a Tesla Powerwall (Moore & Tynan, 2024). |
| Cost to install 4,800 batteries | 4,800 \* 20,000 = $96,000,000 |
| Cost savings | The utility company Green Mountain Power in Vermont has installed 4,800 batteries in homes. Each year, they estimate that they save $3 million in reduced energy costs which could be passed onto the consumer (*GMP’s Request to Expand Customer Access to Cost-Effective Home Energy Storage Through Popular Powerwall and BYOD Battery Programs Is Approved*, 2023). |
| Cost saving per battery | 3,000,000/4,800 = $625 per year |
| The average electricity bill for an apartment in NYC in 2019 was $78.20 a month (Lidner, 2024). | The average yearly electricity bill would be $938.40 (78.2\*12 = 938.4 ). |
| Percent of electricity bill saved each year | This means that each apartment with a battery could save up to 66.7% of their electricity bill each month (625/938.4). |
| Percent of electricity bill saved each year with 50% profit sharing | If 50% of the profits went to the private partners and or the utility companies, it would still reduce electricity bills by over 30% while still bolstering reliability. |
| Average lifespan of a battery (Moore & Tynan, 2024). | 10-20 years |
| PV of cost with a discount rate of 2% | $56,325,695.59 |
| PV of cost with a discount rate of 7% | $64,183,418.68 |

**Appendix D: Electricity Distribution Upgrades Costs**

|  |  |
| --- | --- |
| Facts/Assumptions | Cost |
| Operation and maintenance costs of distribution infrastructure by type (cost per mile) (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). | Overhead transmission: $4,000 - $37,000  Underground transmission: $4,000 - $100,000  Overhead distribution: $1,700 - $22,000  Underground distribution: $900 - $36,000 |
| New transmission by infrastructure type (cost per mile) (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). | Overhead transmission: $1.3mm - $11mm  Underground transmission: $7.2mm - $32mm  Overhead distribution: $120,000 - $3.6mm  Underground distribution: $4mm - $7.2mm |
| Replacement of transmission by type (cost per mile) (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). | Overhead transmission: $930,000 - $7.2mm  Underground transmission: $3.6mm - $23.7mm  Overhead distribution: $430,000 - $3.6mm  Underground distribution: $3.6mm - $7.3mm |
| NYC has 37,000 miles of overhead cables (The Benefits, Costs, and Economic Impacts of Undergrounding New York’s Electric Grid, 2023). | N/A |
| Cost to underground 5% (assumption) of overhead cables using the lowest cost estimate | 37,000 \* .05 \* $4mm = $7.4 billion |
| Cost of operation and maintenance (using the lowest estimate) for 40 years which is the expected lifespan of underground power lines which have a shorter expected lifespan than above ground lines. (Overhead Vs. Underground Fact Sheet, n.d.) | 4,000 \* 37,000 \* .05 = $7,400,00 per year |
| PV of cost with a discount rate of 2% | $7,456,584,531.32 |
| PV of cost with a discount rate of 7% | $7,008,520,085.10 |

**Appendix E: Disaster Preparedness Costs**

|  |  |
| --- | --- |
| Facts/Assumptions | Costs |
| Pilot program size | 30 community centers  100 households  10 years |
| Information Campaign | Department of Health & Human Services spent $250 million for a 5-month informational campaign (*COVID-19*, 2022) |
| Disaster supplies[[5]](#footnote-5) | Dry ice:  $0.80 per pound (*Dry Ice*, 2024)  5 pounds per family (*Keep Foods Safe During a Power Outage*, 2022)  .8 \* 5 \* 100 \* 30 = $12,000  Insulin:  About 3% of the population uses insulin (Lin et al., 2023)  Price of insulin per month $35 (*New HHS Report Finds Major Savings for Americans Who Use Insulin Thanks to President Biden’s Inflation Reduction Act*, 2023)  35 \* 3 \* 30 = $3,150 |
| Administrative costs | Administrative costs associated with disaster relief come from delivering technical assistance, managing grants, staff salaries, planning and more (*Management Costs*, n.d.).  FEMA spent $12.7 billion in administrative costs between 2004 and 2013 (*Opportunities Exist to Strengthen Oversight of Administrative Costs for Major Disasters*, 2014).  This is an average of $1.4 billion per year (12,700,000,000/9 = 1,400,000,00)  This is an average of $28 million per state every year(1,400,000,000/50 = 28,000,000)  Assuming that the cost is an additional 1%, the cost would be $280,000 which would be enough to pay 3 or 4 employees to oversee the program (28,000,000\*.01 = 280,000) |
| Generator installations | Estimated energy usage of a large community center/church type building (*DCAS Managed Building Energy Usage*, 2022) 30,000 MMBTUs  30,000 MMBTUs = 8,800MWh  Diesel Generator $30,000 - $40,000 (*50kW Diesel Generators*, n.d.)  30 generators \* $30,000 \* installation costs = $900,000 |
| Cost of fuel | Diesel generators can use 50 gallons per hour (“Diesel Generator Fuel Consumption Chart,” n.d.)  Cost of diesel fuel $4.5 per gallon (*Gas Prices*, n.d.)  $225 per hour \* number of generators \* number of hours operating \* number of outages  Cost of fuel $81,000. (225 \* 30 \* 4 \* 3 = $81,000) (the 4 hour assumption comes from how long batteries would be able to supply the essential appliances in the average home) |
| PV of cost with a discount rate of 2% | $248,540,464.51 |
| PV of cost with a discount rate of 7% | $236,413,787.69 |

**Appendix F: List of Figures**

Figure 1. Average duration of total annual electric power interruptions, United States (2013-2021) in hours per customer (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023)

A graph with blue bars

Description automatically generated

Figure 2. Global average surface temperature (Lindsey & Dahlman, 2024)

A graph showing the growth of the year

Description automatically generated with medium confidence

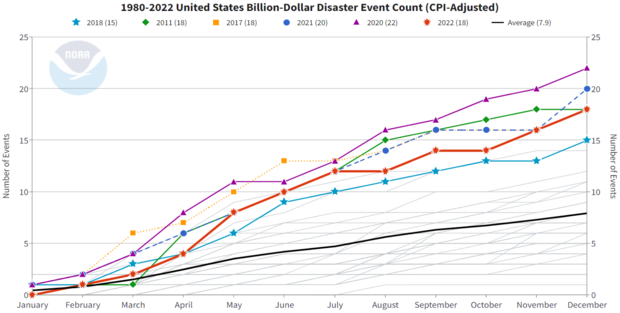
Figure 3. Number of CPI-adjusted billion-dollar disasters in the U.S. (1980-2022) (Smith, 2023)

Figure 4. Average duration of total annual electric power interruptions, United States (2013-2021) in hours per customer (*Annual Electric Power Industry Report, Form EIA-861 Detailed Data Files*, 2023)

A graph of blue and black bars

Description automatically generated

**Appendix G: List of Tables**

Table 1. Evaluated Outcomes by Policy Option

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Status Quo | Disaster Preparedness | Distribution Infrastructure | Battery Storage |
| Equity | Low | Medium | Medium | High |
| Environmental Impact | Medium | High | Medium | Low |
| Administrative Feasibility | High | Medium | Low | Medium |
| Cost  (Range based on 2% and 7% discount rates) | $14.49 – $39.59 million | $236.4 – $248.5 million | $7.01 – $7.46 billion | $56.36 – $64.18 million |

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1. New York City’s Environmental Justice Interagency Working Group defines environmental justice as “The fair treatment and meaningful involvement of all persons, regardless of race, color, national origin or income, with respect to the development, implementation and enforcement of environmental laws, regulations, policies and activities and with respect to the distribution of environmental benefits. Fair treatment means that no group of people, including a racial, ethnic or socioeconomic group, should (i) bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal and commercial operations or the execution of federal, state or local programs and policies or (ii) receive an inequitably low share of environmental benefits.” (New York City’s Environmental Justice for All Report Scope of Work, 2021, p. 6) [↑](#footnote-ref-1)
2. Inverters convert the DC electricity that is stored in most batteries back to AC which is needed to sell electricity back to the grid (*Understanding Solar Energy*, n.d.). [↑](#footnote-ref-2)
3. “Notify NYC” is available in the following languages: English, Arabic, Bengali, Chinese, French, Haitian Creole, Italian, Korean, Polish, Russian, Spanish, Urdu, Yiddish, and American Sign Language (ASL) (Messaging Toolkit from NYC Emergency Management, n.d.). [↑](#footnote-ref-3)
4. Electricity demand is highest in the morning before people go to work and at night when people get home (*Hourly Electricity Consumption Varies throughout the Day and across Seasons*, 2020). [↑](#footnote-ref-4)
5. For the purposes of this analysis, these costs are currently considered up-front but would likely be purchased when the power outage is likely or has already happened. Including several of these costs throughout the 10 year period does not have a large impact on the resulting PV of costs [↑](#footnote-ref-5)