Intro:

As the climate warms, the incidence and duration of power outages across the US is increasing. US electrical customers experienced an average of 8 hours without power in 2020—the longest duration on record. 40-60% of these outages were caused by severe weather events. Aging electrical grid components, already at risk of failure, were not built to withstand previously rare extreme weather events now common with climate change. Additionally, climate-change induced heat and cold events will increase electricity use, outstripping supply, and causing outages.

Power outages threaten health in several ways. Power outages disable air conditioners and heaters, exposing those affected to extreme temperatures. This heat and cold exposure may cause or exacerbate respiratory and cardiovascular illness. Prior epidemiology studies have found elevated cardiovascular and respiratory hospitalizations up to one week after power outage exposure, and associations may be stronger when outdoor temperatures are extreme. Loss of electricity to elevators, mobility devices such as wheelchairs, refrigerators, and life-sustaining electricity-dependent medical devices such as at-home ventilators and oxygen tanks also threatens cardiovascular and respiratory health. These pathways may explain associations between power outages and cardiorespiratory hospitalizations, as well as mortality.

Older adults (those aged >64) may be particularly vulnerable to health consequences from power outages. 70-86% of older adults already live with cardiovascular disease (CVD), and are vulnerable to exacerbations from outage exposure. 3.5% of older adults use electricity-dependent medical equipment such as ventilators and oxygen tanks at home to treat conditions like COPD. Loss of power to these devices can be life-threatening. Because of aging-related thermoregulation changes, heat and cold exposure cause more health consequences in older adults compared to older adults. Older adults also have higher rates of other underlying health conditions, increased reliance on mobility devices and elevators, and are more socially isolated than younger adults, putting them at higher risk for health consequences from power outage.

Power outage and heat exposure has also been associated with increased mortliaty. Loss of electricity to elevators, refrigeration, and electricity-dependent medical devices such as at-home ventilators and oxygen tanks also threaten cardiovascular and respiratory health, and may cause falls or other injuries. Power outages have been associated with

and lpose a serious risk to cardiovascular and respiratory health in older adults.

Power outages may cause a variety of adverse health events, including temperature-related illness, injury, and carbon monoxide poisoning. They also disrupt electricity-dependent medical equipment. In New York State, studies have found associations between outages and cardiovascular hospitalizations in adults and in children, with outages increasing all-cause hospitalization risk by X% in adults and increasing injury-related hospitalization risk by Y%.

These outages pose a serious risk to cardiovascular and respiratory health in vulnerable populations such as older adults. 70-86% of older adults already live with cardiovascular disease (CVD). 3.5% of older adults use electricity-dependent medical equipment like ventilators and oxygen tanks at home to treat conditions like COPD, and loss of power to these devices can be life-threatening. Older adults, especially those with preexisting CVD, are also more vulnerable to cardiovascular or respiratory disease exacerbations from heat or cold exposure if air conditioning, fans, or heaters are unusable during an outage. Outages may also result in loss of power to mobility devices like elevators and power wheelchairs, and more severe outages can lead to loss of clean water and refrigeration, threatening health.

Despite the clear risks of power outage to vulnerable populations, research on power outage exposure and health has been limited by exposure data availability. Studies have used large-scale disasters, like hurricanes, as a surrogate for outages across a broad area (e.g., an entire city) for days or weeks following an event. While useful for understanding the impacts of outages as part of disasters, this type of study doesn’t allow us to disaggregate the effects of outages alone from the disaster scenario. As outages become more common with climate change, understanding the downstream health effects of power outage can inform prevention efforts.

In our preliminary work, we assembled the first nationwide dataset describing hourly county-level power outage exposure from 2018-2020, based on data from poweroutages.us. In this paper, we leverage this county-level daily data of outage exposure in the year 2018 along with Medicare hospitalization data to describe the relationship between power outage exposure and hospitalization risk in older adults 65+ in the US nationwide.

As the climate warms, the incidence and duration of power outages across the US is increasing[[1]](#endnote-1),[[2]](#endnote-2),[[3]](#endnote-3). The US electrical grid is aging[[4]](#endnote-4),[[5]](#endnote-5), and was not built to withstand previously rare extreme weather events now common with climate change. US electrical customers experienced an average of 8 hours without power in 2020—the longest duration on record[[6]](#endnote-6), with 40-60% of these outages caused by severe weather events. Current grid infrastructure was also not designed to meet increased demand for electricity due to climate change[[7]](#endnote-7),[[8]](#endnote-8), which may strain the grid, further increasing power outage risk.

Power outages may cause a variety of adverse health events, including temperature-related illness, injury, and carbon monoxide poisoning. They also disrupt electricity-dependent medical equipment. In New York State, studies have found associations between outages and cardiovascular hospitalizations in adults[[9]](#endnote-9),[[10]](#endnote-10),[[11]](#endnote-11) and in children, with outages increasing all-cause hospitalization risk by X% in adults and increasing injury-related hospitalization risk by Y%.

These outages pose a serious risk to cardiovascular and respiratory health in vulnerable populations such as older adults. 70-86% of older adults already live with cardiovascular disease (CVD)[[12]](#endnote-12). 3.5% of older adults use electricity-dependent medical equipment like ventilators and oxygen tanks at home to treat conditions like COPD, and loss of power to these devices can be life-threatening[[13]](#endnote-13),[[14]](#endnote-14). Older adults, especially those with preexisting CVD, are also more vulnerable to cardiovascular or respiratory disease exacerbations from heat or cold exposure if air conditioning, fans, or heaters are unusable during an outage[[15]](#endnote-15),[[16]](#endnote-16). Outages may also result in loss of power to mobility devices like elevators and power wheelchairs, and more severe outages can lead to loss of clean water and refrigeration, threatening health.

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**Introduction**

Since 2010, electrical power disruptions (outages) have increased in the United States, especially those attributable to major weather events.1 Climate change is projected to increase electric energy demand,2 straining an aging infrastructure system that will be further impacted by extreme weather events.3 Already, over 60% of outages nationwide are attributable to extreme weather events.4 While weather events affect energy infrastructure, access to reliable and affordable energy, or energy security, is also closely intertwined with individuals’ vulnerability to climate change.5

Increasingly, these outage events have been linked to various adverse health effects, including temperature-related illness,6 increased rates of carbon monoxide poisoning,7,8 and disruption of electricity-dependent durable medical equipment.9 However, consistent with the dearth of research on pediatric-specific environmental health outcomes, few population-level studies evaluate the association between outages and children’s health.10 While a single-center study in Cape Town, South Africa, found a 10% increase in pediatric admissions during outages,11 no similar study has been conducted elsewhere, including the United States. With an increasingly vulnerable electrical distribution system, characterization of the downstream health effects of outages can inform primary and secondary prevention efforts.

Of particular concern is the effect of outages on injury hospitalizations, the leading cause of hospitalizations for children in the United States.12 Injury hospitalizations include burns, drownings, falls, environmental exposures, lacerations, transportation injuries, poisonings, firearm injuries, overexertion, and suffocations. Extreme weather events that co-occur with outages, such as anomalously warm temperatures, have been projected to increase injury deaths across the nation.4,13 Several studies have described increases in injuries during severe weather events with co-occurring outages, such as cyclones, but isolating outages as a driver of these associations has proven difficult.10,14–18 Most analyses of outages and health outcomes leverage coarse (e.g., city-wide) spatiotemporal data or focus on single outage events, limiting the precision and generalizability of results.10

An additional challenge in assessing the impact of outage events on health is ascertaining the exposure given significant differences in electricity distribution—such as overhead versus underground transmission lines—and energy use19 across the urbanicity spectrum. Moreover, evidence from outage data at the county level20 and outside the conterminous United States suggests urbanicity affects the prevalence of outages and restoration times.21

Here, we leverage highly spatially resolved outage data in New York State (NYS) to quantify multi-year sub-county outage exposures among rural, urban non-New York City (NYC), and NYC regions of the state. Then, we estimate the association between power outages and pediatric unintentional injury hospitalizations across these geographic strata.

Recently, new national datasets of power outage exposure have become available.

* The incidence and duration of power outage is increasing across the US as the climate warms.
* Current electrical grid wasn’t built to withstand the extreme weather that comes with climate change

1. Wang, Shuai, and Ralf Toumi. "Recent migration of tropical cyclones toward coasts." *Science* 371.6528 (2021): 514-517. [↑](#endnote-ref-1)
2. National Oceanic and Atmospheric Administration. Atlantic Hurricane season takes infamous top spot for busiest on record. Published 2020. Accessed November 24, 2020. <https://www.noaa.gov/news/2020-atlantic-hurricane-season-takes-infamous-top-spot-for-busiest-on-record>

   [↑](#endnote-ref-2)
3. Li, Lin, and Pinaki Chakraborty. "Slower decay of landfalling hurricanes in a warming world." *Nature* 587.7833 (2020): 230-234. [↑](#endnote-ref-3)
4. Casey, J. A., Fukurai, M., Hernández, D., Balsari, S. & Kiang, M. V. Power Outages and Community Health: a Narrative Review. *Current Environmental Health Reports* **7**, 371-383, doi:10.1007/s40572-020-00295-0 (2020). [↑](#endnote-ref-4)
5. Chrobak, U. *The US has more power outages than any other developed country. Here’s why*, <<https://www.popsci.com/story/environment/why-us-lose-power-storms/>> (2020). [↑](#endnote-ref-5)
6. Lindstrom A, Hoff S. U.S. electricity customers experienced eight hours of power interruptions in 2020. U.S. Energy Information Administration. Published November 10, 2021. Accessed January 11, 2022. <https://www.eia.gov/todayinenergy/detail.php?id=50316> [↑](#endnote-ref-6)
7. <https://www.eia.gov/todayinenergy/detail.php?id=54639#:~:text=U.S.%20electricity%20customers%2averaged%20seven%20hours%20of%20power%20interruptions%20in%202021&text=On%20average%2C%20U.S.%20electricity%20customers,hour%20less%20than%20in%202020> [↑](#endnote-ref-7)
8. Casey JA, Fukurai M, Hernández D, Balsari S, Kiang MV. Power Outages and Community Health: a Nar- rative Review. Curr Envir Health Rpt. 2020;7(4):371-383. doi:10.1007/s40572-020-00295-0 [↑](#endnote-ref-8)
9. Dominianni C, Lane K, Johnson S, Ito K, Matte T. Health Impacts of Citywide and Localized Power Out- ages in New York City. Environ Health Perspect. 2018;126(6):067003. doi:10.1289/EHP2154 [↑](#endnote-ref-9)
10. Zhang, Wangjian, et al. "How neighborhood environment modified the effects of power outages on multiple health outcomes in New York state?." *Hygiene and environmental health advances* 4 (2022): 100039. [↑](#endnote-ref-10)
11. Sheridan, Scott C., et al. "The individual and synergistic impacts of windstorms and power outages on injury ED visits in New York State." *Science of the total environment* 797 (2021): 149199. [↑](#endnote-ref-11)
12. Yazdanyar, Ali, and Anne B. Newman. "The burden of cardiovascular disease in the elderly: morbidity, mortality, and costs." *Clinics in geriatric medicine* 25.4 (2009): 563-577. [↑](#endnote-ref-12)
13. Robinson, Marriele, and Annie Shapiro. “Home Health Care in the Dark: Why Climate, Wildfires and Other Risks Call for New Resilient Energy Storage Solutions to Protect Medically Vulnerable Households from Power Outages.” Clean Energy Group and Meridian Institute, June 4, 2019. <https://www.cleanegroup.org/ceg-resources/resource/battery-storage-home-healthcare/>. [↑](#endnote-ref-13)
14. United States Department of Health and Human Services (US DHHS). HHS emPOWER Map 3.0. https://empowermap.hhs.gov/. Published 2019. Accessed 05 June 2019. [↑](#endnote-ref-14)
15. Nunes, Ana Raquel. "General and specified vulnerability to extreme temperatures among older adults." *International journal of environmental health research* 30.5 (2020): 515-532. [↑](#endnote-ref-15)
16. Haman, François, et al. "Human vulnerability and variability in the cold: Establishing individual risks for cold weather injuries." *Temperature* 9.2 (2022): 158-195. [↑](#endnote-ref-16)