# Understanding the Social Impacts of Power Outages:
# A Case Study Comparison across U.S. Cities

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Abstract

Society is heavily dependent on a reliable electric supply; all infrastructure systems depend on electricity to operate. When the electric system fails, the impacts can be catastrophic (food spoilage, inoperable medical devices, lack of access to water, etc.). The social impacts, defined as the direct and indirect impacts on people, of power outages must be explored as the likelihood of power outages and blackouts are increasing. However, compared to other hazards, such as heat and flooding, the knowledge base on the impacts of power outages is relatively small. The purpose of this thesis is to identify what is currently known about the social impacts of power outages, identify where gaps in the literature exist, and deploy a survey to explore power outage experiences at the household level. This thesis is comprised of two chapters, a systematic literature review on the current knowledge of the social impacts of power outages and a multi-city survey focused on power outage experiences.

The first chapter comprised of a systematic literature review using a combined search of in Scopus which returned 762 candidate articles were identified that potentially explored the social impacts of power outages. However, after multiple filtering criteria were applied, only 45 articles met all criteria. Four themes were used to classify the literature, not exclusively, including modeling, social, technical, and other. Only papers that were classified as "social" – meaning they observed how people were affected by a power outage – or in combination with other categories were used within the review.

From the literature, populations of concern were identified, including minority demographics – specifically Blacks or African Americans –, children, elderly, and rural populations. The most commonly reported health concerns were from those that rely on medical devices for chronic conditions and unsafe generator practices. Criminal activity was also reported to increase during prolonged power outages and can be mitigated by consistent messaging on where to receive assistance and when power will be restored. Providing financial assistance and resources such as food and water can reduce the crime rate temporarily, but the crime rate can be expected to increase once the relief expires. Authorities should expect looting to occur, especially in poorer areas, during prolonged power outages. Gaps in the literature were identified and future directions for research were provided.

The second chapter consists of a multi-city survey that targeted three major cities across the United States (Detroit, MI; Miami, FL; and Phoenix, AZ). The survey was disseminated through Amazon's Mechanical Turk and hosted by Qualtrics. 896 participants from the three cities qualified to complete the full version of the survey. Three criteria had to be met for participants to complete the full survey including residing in one of the three target cities, living at their primary address for a majority of the year, and indicate they had experienced a power outage within the last five years.

Participants were asked questions regarding the number of outages experienced in the last five years, the length of their most recent and longest outage experienced, if they owned a generator, how they managed their longest power outage, if participants or anyone in their household relies on a medical device, the financial burden their power outage caused, and standard demographic- and income-related questions. Race was a significant variable that influenced the outage duration length but not frequency in Phoenix and Detroit. Income was not a significant variable associated with experiencing greater economic impacts, such as having thrown food away because of an outage and not receiving help during the longest outage. Additional assessments similar to this survey are needed to better understand household power outage experiences.

Findings from this thesis demonstrate traditional metrics used in vulnerability indices were not indicative of who experienced the greatest effects of power outages. Additionally, other factors that are not included in these indices, such as owning adaptive resources including medical devices and generators in Phoenix and Detroit, are factors in reducing negative outcomes. More research is needed on this topic to indicate which populations are more likely to experience factors that can influence positive or negative outage outcomes.

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There are many people that I would like to recognize that have helped along the way in completing my thesis. Before I begin thanking individual people, there are organizations I would like to acknowledge for their financial support. Thank you to the Urban Resilience to Extreme Events center at Arizona State and the Graduate and Professional Student Association for their financial support of this research. Without it, this thesis would have not been possible.

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Sara, thank you for your mentorship not only in research but also in teaching. You've taught me not only the importance of being a great researcher but also that it is possible to be a good researcher and teacher; something that I thought, before coming to ASU, was nearly impossible to do. I was a little nervous about being a TA in my first semester, but over time you gave me the confidence in myself and showed me that being in academia is my future.

And to my advisor, Dave, thank you for all that you have done over the past two years. For some reason, I still reflect when we first met in Billie Turner's office when I had my initial meeting with him. From that day, something always told me that you would end up being my advisor; I'm glad I listened to that voice in my head. Thank you for all of the advice, the wisdom, the opportunities, and the guidance in helping shape who I am as a researcher and as a person. I've become more ambitious, eager, and passionate about my research interests. And, most importantly, I've learned that it's okay to not be awarded a grant or be rejected from future journals, but more importantly to take the feedback given, sit with the feedback, and apply it for the future so the same mistakes are not repeated.

Last, and most importantly, my family. Mom and Dad, thank you for all of the support in helping me pursue my Master's all of the way out in Arizona. Trust me, as hard as it was for you not to be close, it was just as hard for me. Plus with the pandemic, by no means did it make this any easier. I'm glad I made the decision to move back home when I did and I cannot thank you enough for giving me the necessary environment that allowed me to finish my Master's degree. Luckily, the future has me much closer to you so I can come home when I want to for special occasions. My sister and brother-in-law, Abby and Albert, thank you for being the people I could have random conversations with and for always being available to talk or share the good news with. Also, just having people to geek out about things made a big difference at times, especially during family virtual happy hours. And of course, the little bundle of joy that made me an Uncle and Godfather, my nephew Dominic. You are such a happy child and every time I see you, I can't help but smile. When you were born during my second semester, I couldn't help but feel sad that I couldn't hold you or be near you during the first few months of your life. But now that I am going to be closer, I promise to do my best to make sure I come home more often so I can watch you grow up.

## Introduction

In a report by the U.S. Department of Energy, the United States experienced over 3,000 power outages in 2018 that on average lasted approximately 81 minutes. The report also indicated that the trend of power outages is not decreasing for two reasons. The first reason being more people are reporting power outages, and would partially explain the increase (ASCE 2017). The second reason, however, could be because of the deteriorating electrical infrastructure throughout the United States.

The 2017 American Society for Civil Engineer's infrastructure report card (ASCE 2017), the current condition of all infrastructure in the United States was rated poor and would require $2 trillion in investments over the next 10 years to repair it to an acceptable state. Energy infrastructure was also rated as poor in the same report. Additionally, electrical infrastructure systems are one of the most, if not the most, interdependent infrastructure systems; many systems are dependent on the electrical system continuously operating without interruption (Rinaldi et al. 2001). However, this interdependence places a large strain on electrical infrastructure and can lead to cascading failures within systems that are highly reliant on the electrical grid continuously operating.

One cause for the increased strain comes from the expected increase in global average temperatures. Considering the potential scenarios of the current climate, increasing temperatures will have a profound effect on electrical infrastructure and the interdependent infrastructure systems involved. Increasing temperatures will result in power lines sagging and a decrease in the electricity generation capacity of power plants, especially steam-powered generators. This strain is more prevalent in the southwest United States where summer temperatures require constant use of central air conditioning, and thus a large amount of energy to ensure these devices operate.

Historical data and climatological data, or 30-year averages, are utilized for forecasting daily electrical consumption (Burillo et al. 2017). These data do not account for the population growth and thus the additional electricity that needs to be generated (Burillo et al. 2017; Burillo et al. 2019) Continued use of historical data to forecast the amount of electricity to be generated may lead to periods of constrained power supply and, in a worst-case scenario, more frequent and prolonged power outages (Chester & Allenby 2018; Chester & Allenby 2019). Essentially, increasing temperatures and increasing populations will lead to increased electricity usage, which increases the stress and strain placed on energy infrastructure, quantified by the number of electrical disturbances.

Besides extreme temperatures, other natural hazards such as hurricanes are also a concern when discussing electrical grid failures. Lack of infrastructure hardening and hazard mitigation impacts these systems greatly as they are exposed to the elements and do not have much protection from the impacts of these events, specifically high wind speeds. There is a consensus on what impacts can be expected from these hazards, but we know who is more likely to experience greater social and economic impacts of these hazards.

However, there is a lack of research on the direct and indirect effects on people because of power outages – defined as the social impacts of power outages. Infrastructure impacts that are caused by natural hazards are understood and mitigation strategies have been recommended (e.g. burying power lines underground to reduce exposure to severe wind events). However, what is not clear is how people are affected by power outages (Matthewman & Byrd 2014). Current research demonstrates a great understanding of how households are affected by natural hazards and what can be done to mitigate the impacts of hazards. What is not known currently in the literature is how households experience power outages that are either caused by a hazard or occur independently. Recent work has shown that people of minority demographics and lower socioeconomic statuses are more likely to have experienced longer restoration times, causing an increase in the likelihood that perishable food may spoil and potentially placing a financial burden on these households (Chakalian et al. 2019; Mitsova et al. 2019).

The purpose of this thesis is to identify gaps in the literature on the social impacts of power outages and assess the extent to which power outages differentially affect certain populations. The remainder of this thesis is structured in two chapters. The first chapter details the results of a systematic literature review across 45 peer-reviewed articles and identified via a systematic search in Scopus. This review encompasses all of the social impacts of power outages across North America. The second chapter narrows the focus from that of the literature review to focus on the United States. The second chapter consists of a survey disseminated through Amazon's Mechanical Turk and hosted by Qualtrics. This survey asked for power outage experiences and impacts at the household-level across three major cities in the United States, Detroit, MI; Miami, FL; and Phoenix, AZ. The hypotheses for this thesis are: Research has primarily focused on events that have caused significant power outages within a limited geographic boundary, confined primarily to the United States, and that research has focused more on the technical impacts of power outages. Second, households of minority races and ethnicities experienced more frequent and prolonged power outages. Those of lower socioeconomic status experienced greater economic impacts because of power outages, such as having thrown food away and less likely to receive assistance during the outage. These populations also experience greater impacts as they may lack sufficient finances to replace goods that may have spoiled because of a power outage.

## Understanding the Social Impacts of Power Outages in North America:
## A Systematic Review

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ABSTRACT

As the global population continues to grow and increase demand on already strained electrical infrastructure, the likelihood of power outages will also increase. While researchers understand that the number of electrical grid disturbances is increasing, we do not understand how increased power outages will affect a society that has become increasingly dependent on reliable electric supply. This systematic review aims to understand how power outages have affected society and demonstrate the populations of concern that may experience greater effects and health effects during previously experienced prolonged power outages. Based on search parameters, 762 articles were initially identified of which only 45 discussed the social impacts of power outages in North America. According to the existing research base, minority demographics, especially Blacks or African Americans, those of lower socioeconomic status, children, elderly, and those living in rural areas experienced greater impacts from previous power outages. Additionally, criminal activity increased during prolonged power outages and acts, such as looting, should be expected. Financial assistance or providing resources to replace spoiled goods can reduce the crime rate.

### I.) Introduction

The most recent report from the Intergovernmental Panel on Climate Change (IPCC) raised cause for concern that heat waves will cause a spike in demand for electricity which in turn will lead to brownouts – intentional or unintentional drops in voltage to conserve electricity during emergencies – and blackouts (Revi et al. 2014). Similarly, the 2017 American Society for Civil Engineers (ASCE) infrastructure report card rated the current condition of electrical infrastructure in the United States as poor. The ASCE estimated that over two trillion dollars would be required to restore the nation's electrical infrastructure to acceptable conditions (ASCE 2017). This frail and failing infrastructure will be further stressed by extreme weather events, climate change, and increasing population and demand for reliable electricity (Anderson & Bell 2012; Matthewman & Byrd 2014; USGCRP 2018). The current infrastructure was not designed to withstand the capacity of a rapidly increasing and urbanizing global population and is vulnerable due to outdated design standards (Chester & Allenby 2018; Chester & Allenby 2019). The system as designed is highly interdependent with other critical systems, such as water purification and communication networks; any failures within the electrical system can lead to failures in other systems that depend on continuous electricity (Rinaldi et al. 2001). As a consequence, scholars anticipate that the likelihood of blackouts, and their consequences, will increase in the coming decades (Anderson & Bell 2012; Matthewman & Byrd 2014; Burillo et al.

2017). Infrastructure that is robust and flexible to the effects anticipated in the future climate is essential to mitigate impacts from future shocks and stressors (Chester & Allenby 2018). Future infrastructure design must consider all potential scenarios of the future climate and adapt infrastructure accordingly (Burillo et al. 2017).

People are affected adversely by power outages. Physical health impacts are a large concern during power outages, especially for those that rely on an electricity-dependent medical device (Miles & Jagielo 2014; Miles et al. 2014; Esmalian et al. 2019). Mental health issues also become a concern during power outages, as those affected are living in temporary uncertainty about how long the event will last and how it may impact them (Rubin & Rogers 2019). However, health impacts are not the same in every household, causing power outages impacts to be complex, as not all factors of every individual household may be known. Thus, there is a great concern to understand how power outages may impact people as various populations experience power outages differently because of their unique household situations.

The purpose of this review is to understand how people are affected during power outages by utilizing 42 years (1978-2019) of academic literature. To the best of our knowledge, this is the first review that explores the social impacts of outages, but two systematic reviews were identified through our review. Klinger et al. (2014) conducted a similar review, but only focused on two years of peer-reviewed literature (2011-2012) and identified 20 relevant articles that covered only the health impacts of power outages. They also utilized media pieces to further augment what the media had reported on to investigate the frequency, impact, and geographical distribution of power outages (Klinger et al. 2014). This is similar to our review, however, we did not limit to only health impacts and did not utilize media pieces. The psychological and behavioral impacts of power outages were the focus of Rubin & Rogers (2019) and highlighted the takeaway messages that need to be addressed by public leaders for future outages. Rubin & Rogers identified 47 articles in their review on how the public reacted after a major loss of electricity, but similar to Klinger et al. they did not have a geographic boundary to their research. While these reviews examined similar topics, our review explores the social impacts of power outages through a comprehensive approach, rather than focusing on a particular portion of the literature and focused within North America. We did not limit the geographic scope to only the United States as portions of Canada and Mexico are included in two interconnections that exist within the grid, the Eastern Interconnection and the Western Interconnection (Learn More About Interconnections, n.d.).

When discussing the social impacts of power outages, we are considering the impacts to people and households that could occur during a power outage, regardless of how the outage occurred. We are defining social impacts as the direct and indirect effects and impacts people can experience during or after a power outage.

The remainder of this paper is as follows: Section II provides an overview of the systematic review methodology, inclusion and exclusion criteria, and literature selected for this review. In Section III, the findings from the literature are presented and categorized into common themes, accompanied by a discussion of our findings. Finally, in Section IV, we summarize our findings and propose future directions for power outage research.

## II.) Review Methodology

### *A.) Literature Search*

Roughly twenty preliminary searches were conducted to iteratively identify a set of search terms that would identify articles relevant to the research objective (see Table 1 for the searches used to create the list of results for this review). At first, we focused on using search terms that were relevant to identifying research related to power outages that occurred after a natural hazard. While reading through abstracts of previous searches, it was apparent that we were missing outages that occurred independently, or those that were initiated due to failures within the electric grid system itself, and wanted to include papers related to within our review. Ultimately, we used two separate keyword lists to build a set of candidate articles for inclusion, and subjected articles on each list to inclusion criteria. We searched for articles using Scopus, limiting the search to peer-reviewed literature articles published in English with the search terms present in the title, abstract, or keywords. The first set of search terms, applied in December 2019, used “power outage*” AND “impact*” (adding the asterisk in front of each word allowed for both the singular and plural versions of the terms to be sought and included within the list of literature). This search yielded 513 candidate articles.

**Table 1**. Search terms used that returned the final list used for the systematic literature review.

| Search Number | Terms used | Number of Results |
|---|---|---|
| 1 | “power outage*” AND “impact*” | 513 |
| 2 | "power outage*" OR "blackout*" OR "power failure*" AND "social” OR “health” AND NOT “alcohol*" OR "drink*" OR "micro*" AND DOCTYPE (ar or re) | 560 |
| 3 | #1 OR #2 AND DOCTYPE (ar or re) | 762 |

The second set of search terms was applied in February 2020 to broaden the scope of articles on the social impacts of power outages that were included. The search terms used in the second search were "power outage*" or "blackout*" or "power failure*" and "social” or “health” and not “alcohol*" or "drink*" or "micro*". The limiting terms – terms after AND NOT– removed several papers regarding blackouts caused by a medical reason or because of alcoholconsumption that was identified in the first search. When examining the results from the first search, it appeared we were missing papers from the health perspective of power outages. The second search used a set of terms aimed at expanding the scope of the research further, by attempting to find relevant research from the health perspective, similar to that of Klinger et al. (2014). The second search produced 560 articles.

We did not specifically examine research on modeling power outage patterns, both spatially and temporally, nor does it intend to review the findings of papers that explore the potential impacts that are modeled through simulations of future power outages, providing access to electricity, or maintaining a reliable electric supply. We did limit the geographic scope of papers in this review to North America only due to aspects of the electric grid existing in both the United States, Canada, and Mexico. We also were aware the infrastructure management in North America differs from other countries and that papers located outside of North America were less likely to be written in English, and thus would have to be excluded per our filtering criteria.

***B.) Coding***

The list of literature was first obtained by combining the previously mentioned search phrases. Once combining these with the OR operator in Scopus, the search returned 762 results. We next read the abstracts to determine if each paper potentially examined the social impacts of power outages. After reading through the abstracts the first time, four inductive and inclusive themes emerged: modeling (n = 173), technical (n = 393), social (n = 70), or other (n = 333). Abstracts were then read a second time to classify each abstract into these themes. Papers classified as modeling used a simulation or modeling technique to simulate power outage occurrences. Those classified as technical papers explore the impacts of power outages on physical infrastructure. Social research examined impacts on individuals, households, or demonstrated how power outages impacted critical social services. The other category served as a classification for papers that do not fall under the three previously listed categories. Only those classified as social, either exclusively or in combination with other terms, were subject to additional criteria to determine if they examined the social impacts of power outages and were eligible for inclusion in the full review. This step eliminated 636 papers. Papers that examined a significant weather event, but did not detail the impacts of the ensuing power outage were also excluded. This exclusion criterion appeared in 125 of the first 636 removed papers. Papers that observed the impacts past power outages had, or future outages may have, on the electric grid or other aspects of the electrical grid system were also removed, as these would be classified as a technical paper. Studies that examined a willingness-to-pay or discrete choice experiments were excluded and classified as other. While these studies estimated the number of money people would consider paying to avoid outages, no connection to impacts was made (Carlsson & Martinsson 2008; Abdullah & Mariel 2010). Research that consisted of a biographical account of living in a situation with unreliable electricity, or deploying a model or simulation to show the potential impacts that could affect people were also excluded from this review (Hiete et al. 2011; Kesselring 2017).

After reading the abstracts and while obtaining the papers We subsequently removed 19 duplicate entries and 30 papers that were inaccessible, not written in English, or had insufficient data in the Scopus search returns. We then read the full text of the remaining 77 articles. After the full-text read of each paper, 27 more papers were removed as they did not examine the social impacts of power outages, despite making it through the previous criteria; 50 papers remained. Finally, papers that were focused on areas outside of North America were removed, eliminating nine papers. The authors were aware of 4 additional papers from previous work that were not included in the search results and were added, bringing the final total to 45 papers for this

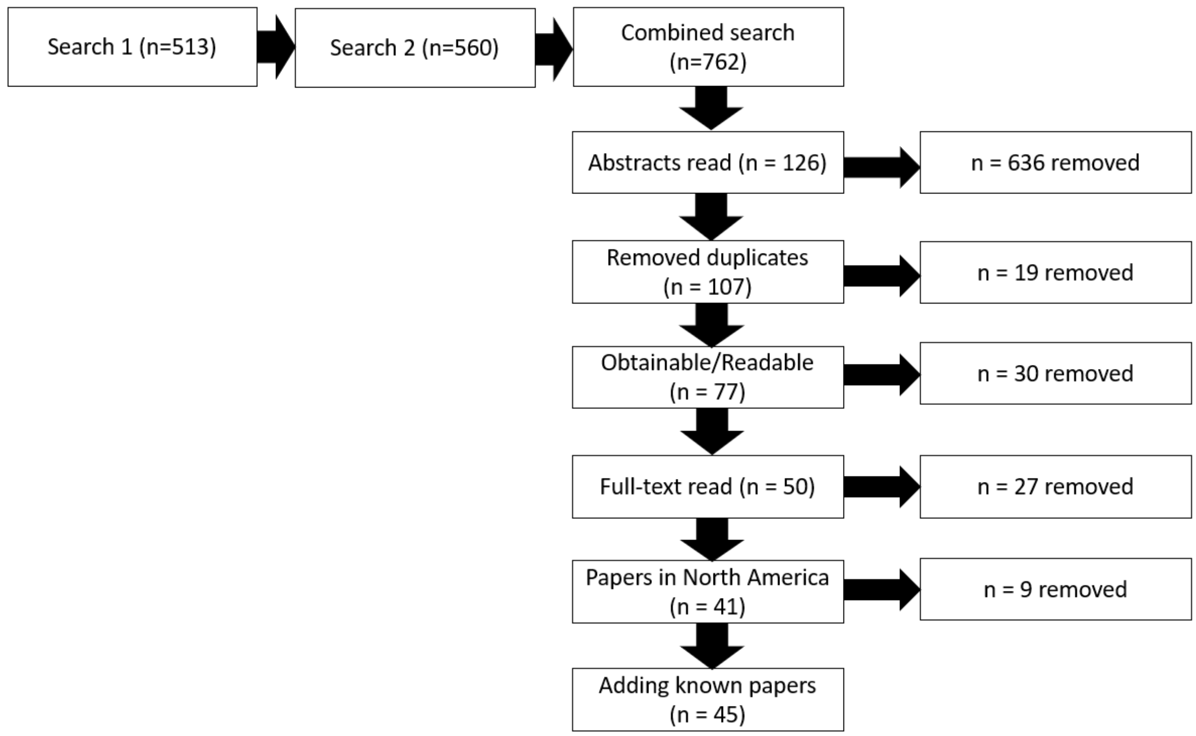


**Figure 1.** A visual depiction of the filtering process to obtain the list of literature used for this review.

review. A visual depiction of this process is displayed in Figure 1. More details about the literature used can be found in Appendix A.

## III). Results and Discussion

### *A.) Descriptive and Thematic Analysis*

From the initial list of 762 papers, we only classified 45 studies as social, meaning that only 6% of the articles focused on the social impacts of power outages. Several papers that were classified as social were also classified into one of the other categories. Of the 45 papers included in this review, six included a statistical modeling component and were categorized as modeling. Five papers discussed components of the hard infrastructure or the technical aspects of power outages and were also labeled technical. Finally, four papers were classified as other as their methods or overall objective did not fit within the scope of a modeling or technical paper.

Of the 45 papers we analyzed, 33 solely focused on the social effects of power failures without addressing one or more of the other categories.

Significant events provide an opportunity to research the social impacts of power outages; however, these are not planned events and can be difficult to anticipate for researchers. The primary focus of the literature we examined was the impacts of power outages during the aftermath of significant weather or geological events. From the 45 papers used in this review, 40 of those examined power outage impacts from 23 different events. The most frequently examined individual events were Superstorm Sandy (2012) and the 2003 blackout that occurred across the northeastern United States and parts of Canada, which were the subject of 7 articles and 6 articles, respectively. The 1977 blackout in New York City, Hurricane Irma (2017), and Hurricane Isaac (2012) were also each the subject of more than one article we reviewed; other events mentioned were examined in the literature only once (see Table 2). The remainder of the research that did not emerge from a significant event (n=5).

We found that articles related to the social impacts of power failures appeared in 37 different journals (see Table 3), suggesting that this research is highly interdisciplinary. Only five journals published more than one article included in this review. These journals included Prehospital and Disaster Medicine (4 publications), Disaster Medicine and Public Health Preparedness (3 publications), the Journal of Environmental Health, Natural Hazards, and the Journal of Infrastructure Systems (each with 2 publications). Journal titles reflected a wide range of disciplines addressing the social impacts of power failure, including public health, geography, sustainability, and energy.

There has also been a rise in scholarship in this field over recent decades (Figure 2). Before the 21st century, we found only four articles on the social impacts of power outages, with the earliest article in our review published in 1978, nine from 2000-2009, and 32 from 2010-2019. However, it should be noted that this increase may correspond to the overall increase in published research within the past decade that was augmented by significant hazards such as Hurricane Isaac and Superstorm Sandy (2012), and Hurricanes Irma and Maria (2017).

We further classified the papers we reviewed based on their methodological approach. Each paper was classified into one or more of the following categories: Case study, interviews, surveys, systematic literature reviews, and other. The most common methods in the articles we

**Table 2.** A list of events and their frequency in the literature reviewed.
*One paper reviewed 9 different ice storms from 1886-2000.

| Event | Number of Papers |
|---|---|
| 1977 NYC Blackout | 4 |
| 1998 Blackout | 1 |
| 1998 Ice storm | 1 |
| 1999, 2003, 2006 Power Outages | 1 |
| 2003 Blackout | 6 |
| 2003 Hurricane Isabel | 1 |
| 2004 Hurricanes | 1 |
| 2005 Florida hurricanes | 1 |
| 2006 Snowstorm | 1 |
| 2006 Windstorm | 1 |
| 2008 Hurricane Ike | 1 |
| 2011 and 2013 snowstorms | 1 |
| 2011 Outage | 1 |
| 2012 Derecho | 1 |
| 2012 Hurricane Isaac | 2 |
| 2012 Superstorm Sandy | 7 |
| 2016 Hurricane Hermine | 1 |
| 2017 Hurricane Harvey | 1 |
| 2017 Hurricane Irma | 3 |
| 2017 Hurricane Maria | 1 |
| March 1991 and February 1994 ice storms | 1 |
| Reviewing past ice storms across the United States* | 1 |
| Rolling blackouts | 1 |
| N/A | 5 |

reviewed were a case study approach (n = 20), followed by interviews (n = 11), and surveys (n = 6). Other methods included reports or summaries of events (n=3), systematic literature reviews (n=2), and other (n=1). To clarify, any research classified as a case study examined a variety of impacts as a result of an event but maintained a focus on the ensuing power outage that occurred after the event (see Table 4).

**Table 3.** A list of journals, and frequencies, where articles for the review were published.

| Journal | Number of Papers |
|---|---|
| American Journal of Disaster Medicine | 1 |
| American Journal of Preventive Medicine | 1 |
| American Journal of Preventive Medicine | 1 |
| American Journal of Public Health | 1 |
| American Society of Civil Engineers | 1 |
| Archives of Surgery | 1 |
| Clinical Toxicology | 1 |
| Computing in Civil Engineering 2019: Smart Cities, Sustainability, and Resilience - Selected Papers from the ASCE International Conference on Computing in Civil Engineering 2019 | 1 |
| Disaster Medicine and Public Health Preparedness | 3 |
| Disasters | 1 |
| Economic Geography | 1 |
| Educational Gerontology | 1 |
| Environmental Health Perspectives | 1 |
| Epidemiology | 1 |
| Evaluation and Program Planning | 1 |
| IEEE Spectrum | 1 |
| Internation Journal of Disaster Risk Reduction | 1 |
| Journal of Community Health | 1 |
| Journal of Emergency Medicine | 1 |
| Journal of Environmental Health | 2 |
| Journal of Infrastructure Systems | 2 |
| Journal of Public Health and Management | 1 |
| Journal of Risk Research | 1 |
| Journal of Toxicology and Environmental Health - Part A: Current Issues | 1 |
| Journal of Urban Health | 1 |
| Natural Hazards | 2 |
| Pediatrics | 1 |
| PLoS Currents | 1 |
| PLoS ONE | 1 |
| Prehospital and Disaster Medicine | 4 |
| Prehospital Emergency Care | 1 |
| Public Health Reports | 1 |
| Science of the Total Environment | 1 |
| Social Space | 1 |
| Sustainability (Switzerland) | 1 |
| Vulnerability, Uncertainty, and Risk: Quantification, Mitigation, and Management - Proceedings of the 2nd International Conference on Vulnerability and Risk Analysis and Management, ICVRAM 2014 and the 6th International Symposium on Uncertainty Modeling | 1 |
| Weather, Climate, and Society | 1 |

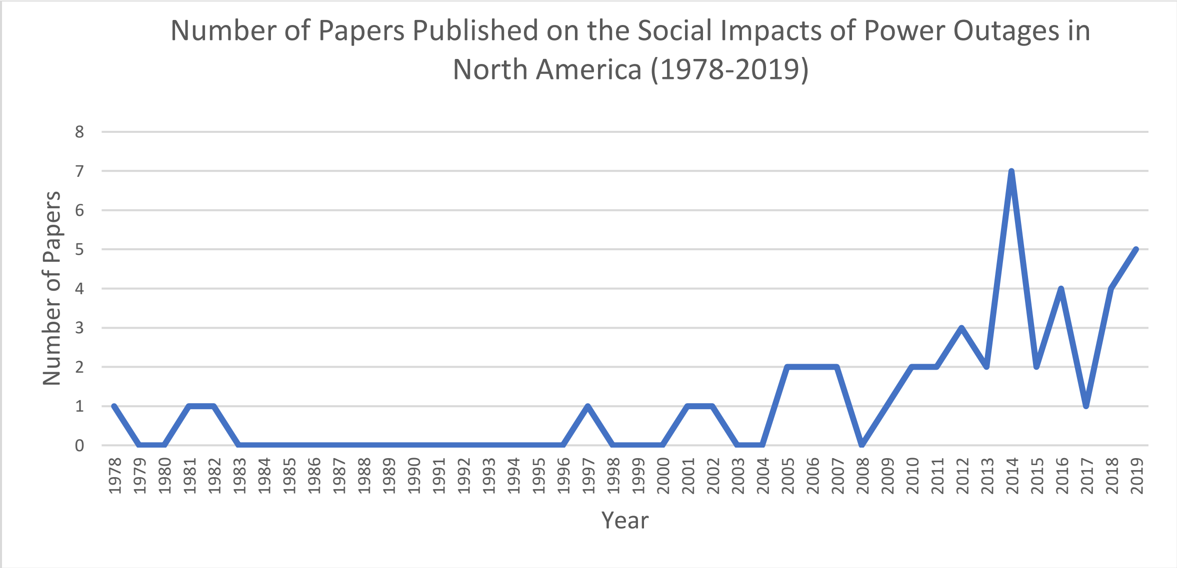


**Figure 2.** A line graph showing the frequency of papers published each year from 1978-2019.

Lastly, the papers found through this review were only modestly cited in the literature, with an average citation count of 10.16 citations per paper (standard deviation = 11.98). The most cited had, at the time of this review, 56 citations (Anderson & Bell 2012), with the next highest being 45 citations (Marx et al. 2006), and followed by 33 citations (Klinger et al. 2014). Most of the papers published before 2000 have a relatively small number of citations, except for Wrenn & Conners (1997) with 30 citations.

**Table 4.** A list of the method types and frequencies used throughout the review.

| Method | Number of Papers |
|---|---|
| Case Study | 23 |
| Interviews | 12 |
| Lit Review | 2 |
| Model | 2 |
| Other | 2 |
| Report/summary | 3 |
| Retrospective Review | 1 |
| Survey | 9 |

### *B.) Findings from the Literature*

This section encompasses the relevant findings from the literature across three inductive themes: populations of concern (n=26), health impacts (n=21), and criminal activity (n=6).

### *1.) Populations of Concern*

Within this review, 26 studies identified one or more populations of concern. Populations of concern identified through this research included children, non-English speakers, minority demographics, elderly, and those that live in rural areas. This sub-section describes the reasons why these groups were identified as populations of concern during power outages.

#### *1.1) Children*

Children are a population of concern during power outages. In February 2016, three million children, under the age of five years, in Nepal were a concern during a period of frequent, and sometimes long-lasting, outages occurred. After Hurricane Sandy, those that were younger, specifically under the age of 17, were at greater risk of being exposed to CO poisoning as they might be less aware of the dangers associated with power outages (Schnall et al. 2017). Fife et al. (2009) also found the number of children affected by CO poisoning was higher than other populations because they relied on technology for entertainment. This activity becomes a danger because children will use their devices near a generator while they are charging, leading to a greater risk of CO poisoning because of their proximity to the generator (Fife et al. 2009).

#### *1.2) Non-English Speakers*

Non-English speakers may not understand the messaging that is provided in English only. Safety messaging emerged as a sub-theme in several studies that examined the intersection of language and power outage communication and messaging. The three studies we found that investigated the role of language consistently found that individuals with limited English proficiency were at higher risk of improper generator use or could not access or understand pertinent safety information (Wrenn & Conners 1997; Burger et al. 2013; Schnall et al. 2017). Information that is available in multiple languages will assist this population most during power outages.

#### *1.3) Minority Demographics*

Minority demographic populations, more specifically Blacks or African Americans, and those of lower socioeconomic status were also reported to be at greater risk of adverse effects during power outages. Muhlin et al. (1981) indicated that areas with greater minority populations were at greater risk to experience increased crime during a power outage. Lin et al. (2016) also noted that those of low sociodemographic status experience greater mental health problems, for example, anxiety, mood disorders, and substance abuse to name a few, because of a power outage. These impacts were present after Hurricane Sandy and highlighted the Bronx area, where roughly 44% of the population is Black according to a 2019 U.S. Census estimate, as a significant place of concern in the aftermath of Hurricane Sandy (Lin et al. 2016).

### *1.4) Elderly*

Elderly populations, especially those 65-74 years old, are also of greater concern during power outages, as they are more likely to be dependent on some type of medical equipment for chronic illness and increased mental health impacts (Anderson & Bell 2012; Lin et al. 2016). Similar to those of lower sociodemographic status, Lin et al. (2016) also found that elderly populations experience greater psychological symptoms during a power outage, such as increased stress, anxiety, depression, and overall in need of greater support — and should be prioritized. Similar findings were noted by Klinger et al. (2014), Gotanda et al. (2015), and Rubin & Rogers (2019). However, Chakalian et al. (2019) found the opposite after Hurricane Irma, noting that households with individuals over the age of 64 were less likely to experience stress or discomfort because of a hurricane or a blackout. This group was more self-reliant in mitigating impacts on their overall well-being and were more independent during these times than initially hypothesized (Chakalian et al. 2019).

### *1.5) Rural Populations*

Rural populations are more likely to experience longer outages than those living in urbanized areas (Call 2010). In urban settings, the concentration of power lines that are considered high priority is centralized and located within proximity, leading to faster response and restoration times compared to surrounding rural areas (Call 2010; Román et al. 2019). Thus, providing rural areas with greater assistance after a significant event or during a prolonged power outage is necessary as electrical infrastructure in these areas is not as clustered as urbanized areas (Román et al. 2019). However, due to previous experiences, this group may also be more prepared for longer outages, and better anticipate longer restoration times for future events.

*1.6) Other Populations*

An observation from Lin et al. (2011) indicated those of higher socioeconomic status should be considered if a power outage occurred during the summer season as they are more likely to experience heat-related symptoms. Lin et al. argued this group may have less experience dealing with uncertainty, for instance, a power outage, and less knowledge about how to keep cool in their homes during the summer months without air conditioning. A second reason could be that this population can afford healthcare and therefore be able to receive treatment if they are presenting heat-related symptoms and stay at the hospital as a way to keep cool until power is restored at their residence. Those of higher income are more likely to own resources that are necessary to stay cool in warmer temperatures. However, when these resources become unavailable during a power outage, those of higher-income could have a lower capacity in dealing with warmer temperatures, both indoor and outdoor, and maybe less aware of cooling strategies.

In the event of a power outage, the list of populations identified in this review serves as a starting point for practitioners to assess preparedness. Those that rely on medical equipment or suffer from chronic conditions are dependent on hospitals having reliable backup generators and to run the generators until power is restored. Therefore, both those that need medical equipment and those that provide medical services and care, including pharmacies, must be prepared for an event that may last for a prolonged power outage. Should supplies run low, medical providers must be able to connect their customers with additional resources that can provide services until power is restored (Arya et al. 2016).

*2.) Health Impacts*

This subsection examines the 21 studies that observed the health impacts of previous power outages and how these events impact healthcare.

Health impacts were a highly present theme observed in the literature. One of the main concerns from the health sector, when a major power outage occurs, is the increase in the emergency department (ED) visits due to carbon monoxide (CO) poisoning. CO poisoning primarily resulted from improper and unsafe usage of generators during a power outage, as noted by Wrenn & Conners (1997), Riddex & Dellgar (2001), Van Sickle et al. (2007), Fife et al. (2009), and Call (2010). An increase in the number of hospital and ED admissions due to carbon monoxide was reported by Baer et al. (2011) after a significant windstorm in the state of Washington in December 2006. A similar pattern was observed after a Colorado snowstorm in 2006, when 264 people, presented with CO poisoning symptoms (Musciatello et al. 2006). Similarly, Schnall et al. (2017) also noted 566 cases of carbon monoxide poisoning post-Superstorm Sandy. Hospitals and emergency departments should expect an increase in emergency department visits because of incidents that occur after the hazard (Muscatiello et al. 2006; Johnson-Arbor et al. 2014; Schnall et al. 2017).

Food-related illnesses also increase during and after power outages due to the consumption of spoiled food. Marx et al. (2006) noticed an increase in ED visits in New York City after the 2003 Northeast blackout for symptoms of diarrheal illness. The authors were not able to establish a relationship, as additional samples and data would be needed to further support their findings. However, the authors stated that spoiled food after the blackout may have caused an increase in ED visits (Marx et al. 2006).

Healthcare system workers are more likely to be overstressed and overworked during a power outage. The blackout that occurred in 2003 across the northeastern United States demonstrated that Specialists-in-Poison Information (SPIs), workers in the Poison Control Center, were greatly overworked and had trouble finding time to rest during and after the blackout (Klein et al. 2007). Workers experienced a significant increase in call volume both during the blackout and after power was restored.

In addition to those that require hospitalization or care at a medical facility, people that require at-home care or are dependent on medical equipment outside of a medical facility, are vulnerable during power outages. Patients that require home oxygen therapy (HOT) treatments need assistance before the storm so they can prepare for the post-event period without power; power outages are when patients that are dependent on HOT should receive extra supplies to last until power is restored (Esmalian et al. 2019). Thus, planning for large-scale events, and more specifically planning where those who rely on electronic medical equipment need to be transported to receive the proper treatment, is a vital component of power outage preparedness, response, and recovery (Miles & Jagielo 2014; Miles et al. 2014). Those that are dependent on medical devices, other than HOT equipment, are also more likely to call for emergency services during an outage. (Rand et al. 2005). During the 1977 New York City blackout, over 70,000 emergency calls were received in the 48-hour blackout, while only 18,500 calls were average for 48 hours under power-on conditions (Imperato 2016). Those that require regular medical treatments (e.g., dialysis and other specialized medical practices) are vulnerable during power outages because of the possibility of missing treatments and not having a facility with reliable electricity to receive that treatment (Abir et al. 2013).

Other potential injuries may occur during a power outage. Palmieri & Greenhalgb (2002) found that with winter storms, there was an increase in the number of cases relating to heater burns. During power outages, some people may resort to abusing substances to cope with the unusual times, such as alcohol and drugs, adding to the danger of power outages (Jani et al. 2006; Lemieux 2014; Lin et al. 2016). Jani et al. (2006) noted that of the 32 deaths examined from Hurricane Isabel, alcohol appeared to be involved in eight deaths and marijuana in one. All deaths occurred while completing tasks that require coordination and good judgment, for instance, driving in dangerous weather conditions (Jani et al. 2006). Communication and messaging about the dangers of using these substances during and after extreme weather events are critical to limit the number of indirect deaths (Jani et al. 2006).

*3.) Criminal Activity*

Criminal activity is theorized to occur post-hazard, but this is a misconception; no articles that were included in our review demonstrated that after a hazard, criminal activity increased. When power outages occur independently of a hazard, crime and various criminal acts were more likely to occur due to an increase in motivation to commit crimes (Lemieux 2014; Matthewman & Byrd 2014). Power outages and blackouts provide an opportunity for fraud, theft, and exploitation (Matthewman & Byrd 2014). Businesses located in poorer areas were more likely to be looted than businesses located in areas with few poor people (Sugarman 1978; Wohlenberg 1982). Wohlenberg (1982) found that business owners in poorer areas that were heavily looted during a power outage have intentionally burned their businesses. Other crimes not planned for may increase, such as generator theft and breaking into property with an alternate power supply (Riddex & Dellgar 2001). If a blackout disrupts public services, authorities must expect looting to occur (Wohlenberg 1982).

Despite the potential for crime to occur, crimes can be mitigated with financial support and from local officials (Lemieux 2014). Financial assistance and food can be provided to reduce the crime rate during a power outage, but this solution is only temporary as the crime rate would increase once the initial relief has expired (Rubin & Rogers 2019). This increase in crime could be a result of people requiring further assistance and additional assistance cannot be provided, which could lead to distress and unhappiness within certain populations.

### *C.) Gaps within the literature*

While reading through the papers included in our review, knowledge gaps that would advance the field were identified. With the number of outages expected to increase, the majority of the literature has focused on power outages that lasted for more than one day. Future research should put more effort into understanding how people are affected by more frequent power outages compared to longer and less frequently occurring power outages. While shorter outages may seem to be a small nuisance, others may see more frequent outages as a great concern, especially if they rely on a breathing machine or struggle to consistently afford essentials. Knowing what impacts are anticipated with outages at certain lengths of time can help local organizations respond more effectively by providing a sufficient amount of supplies that can aid those affected, especially those of lower-income, that can last until power is restored without requiring refrigeration. Lastly, how power outage impacts vary depending on the season. Moreover, examining how are power outages different in the winter season compared to an outage that would occur in the summer.

## IV.) Conclusion

In this review, we identified 45 articles that explored the social impacts of power outages. A majority of candidate articles covered the technical impacts of power outages to electrical infrastructure, demonstrating a need for an increase in research on social impacts. Many populations of concern were identified including children, elderly, minority demographics- such as Blacks or African Americans-, and those that live in rural areas. The greatest health concern that emerged during power outages was CO poisoning because of unsafe generator use during power outages. Hospitals should expect an increase in ED visits as more people will present with CO poisoning-related symptoms or require an operating medical device since patients' devices cannot work without electricity. Criminal acts increase during power outages, but crime rates can be reduced temporarily during prolonged power outages by providing assistance and consistent updates on where to receive assistance and when power is expected to be restored. Looting most likely occurs in areas with more poor people; authorities should expect looting during prolonged outages to occur as people see power outages as an opportunity to commit criminal acts.

Future work can expand on this review by either addressing the gaps identified in the literature. The financial impacts of power outages have been under-investigated and would serve prudent those of lower socioeconomic status, as they tend to struggle to afford essentials. More frequent power outages were not observed in this review and must be explored soon as we are experiencing more frequent electrical disturbance in the grid. More frequent outages may leave those that rely on medical devices for their chronic more anxious because of the uncertainty of when their next power outage will occur. Additionally, refrigerators are not able to keep perishable food stored at proper temperatures after 6 hours without power (FEMA 2018). Increased power outages may lead to an increased likelihood of more food being spoiled and thrown away. Research also needs to expand geographically. An abundance of opportunities exist in researching how countries outside of North America, especially outside of the United States, have experienced power outages and what strategies are used to manage the situation until power is restored. Exploring the variety of impacts power outages may cause depending on the season they occur – how power outage impacts vary if they occur in the summer season or the winter season.

Because of the increasing trend of reported electrical grid disturbances, research on the social impacts of power outages is becoming increasingly significant as the future climate comes into fruition. Investments must be made into improving the conditions of electrical infrastructure to reduce the number of power outages, but also to increase the robustness of the system and lessen the consequences of failures with interdependent systems, should failures occur. There is a great need to address the potential impacts of the future climate as not only will the impacts affect the already deteriorating infrastructure in the United States, but ultimately an increasingly electricity-dependent society will be affected the most by electrical system failures.

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## Understanding Household Power Outage Experiences across U.S. Cities

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ABSTRACT

Household power outage experiences vary based on household situations. While there are methods to anticipate where the greatest impacts of a hazard may occur, these methods were not designed to anticipate the secondary impacts of hazards, such as power outages. To understand how households experience power outages in different geographies, 896 participants were surveyed across three cities in the United States: Detroit, MI; Miami, FL; and Phoenix, AZ. Participants were recruited through Amazon's Mechanical Turk (MTurk) service to complete a survey, hosted in Qualtrics. We hypothesized that those of minority races, specifically non-Whites, experienced more frequent and longer power outages and lower socioeconomic status were more likely to have experienced greater economic impacts, such as having thrown food away and less likely to receive help during their longest outage. Concerning race, we found that non-Whites in Phoenix and Detroit were more likely to experience longer outages than Whites, however, this association was not present in Miami. Income was not a strong factor with having thrown food away because of a power outage and not receiving assistance during the longest reported outage. Through this research, we demonstrated that using social vulnerability indicators – race and income – were not factors associated with more frequent and longer power outages. Further assessments in varying geographical and political contexts are necessary to increase understanding of how households experience power outages. This research is necessary as the likelihood of power outages is expected to increase, given the increasing trend of recent reported electrical disturbances, and the additional strain caused by increasing demand from a growing population will have on the poor electrical infrastructure in the United States.

### I.) Introduction and Background

In 2017, the United States experienced more than 3,000 power outages that lasted on average approximately 81 minutes (U.S. Department of Energy 2018; Chakalian et al. 2019). Power outages are common events that co-occur with natural hazards. Rising global temperatures will increase electricity demand, but will simultaneously reduce the efficiency of the electrical transmission and distribution infrastructure. Therefore, increasing the likelihood of periods of constrained electric supply, which increases the likelihood for brownouts and blackouts (Van Vilet et al. 2012; Bartos & Chester 2015; Chakalian et al. 2019).

Most of the existing literature examines power outage impacts from a technical perspective for instance how hazards impact the electric grid (Andersson et al. 2005), cascading effects with interdependent systems (Buldyrev et al. 2010; Dobson & Newman 2017), and performance impacts caused by long-term stressors, such as urbanization and global climate change (Miller et al. 2008; Hayhoe et al. 2010; Dirks et al. 2015; Burrillo et al. 2016; Chakalian et al. 2019). Cascading effects are known as the secondary effects that result from a failure in one component of a tightly connected system; the current electrical infrastructure system within the United States is a prime example of a tightly coupled system (Rinaldi et al. 2001; USGCRP 2018). Little is known about the social impacts of power outages at multiple scales, especially the household and neighborhood levels (Matthewman & Byrd 2014). These types of failures threaten the health and comfort of all affected households. While this body of literature on the social impacts of power outages is limited, the literature that does exist approaches blackout hazards from a health perspective (i.e. Klinger et al. 2014). However, it is currently difficult to establish a relationship between social characteristics like age, socioeconomic status, race, ethnicity, and other demographic variables, and an individual's or household's vulnerability to impacts from power outages (Chakalian et al. 2019). Establishing this relationship is important because households are unique and comprise of various racial backgrounds and income statuses that can either enhance or reduce vulnerability to power outage impacts.

Natural hazards and associated power outages present an excellent research opportunity, but power outages also can occur independently of a natural hazard. Therefore, research should not only be solely focused on preparations for extended power outages that result because of a hazard but should also be focused on understanding how populations of concern have to quickly adjust their lives because of an outage. Those with medical conditions are especially at greater risk because of the inability to plan for treatments during the outage and must find alternative methods of receiving their treatment or risk missing treatments (Abir et al. 2013). Additionally, those of lower-income are also more vulnerable to power outages as they may have to utilize additional funds to replace spoiled food and are more likely to experience mental health problems (Lin et al. 2016).

While there are several potential reasons for the variance in power restoration times, recent research after Hurricane Irma has indicated that environmental injustices may be a result of this variance in power restoration (Chakalian et al. 2019; Mitsova et al. 2019), but the results are not generalizable to the U.S. population. Chakalian et al. conducted semi-structured interviews with representatives from 42 households affected by Hurricane Irma in two Florida counties. Their results demonstrated a need for larger sample sizes, however, their findings were also geographically limited. Similarly, Mitsova et al. (2019) conducted telephone surveys with nearly 1,000 participants affected by Hurricane Irma. Their sample size was much greater than Chakalian et al., but their findings were not generalizable to the larger population due to limited geographic coverage, 30 counties in central and southern Florida. In contrast, the work here deployed a survey across three different cities in different geographic regions across the United States to capture household experiences during a power outage, regardless of how the outage occurred.

This chapter extends this line of research, seeking to answer the question "Who is likely to experience greater impacts because of power outages?" through a household survey conducted on a convenience sample from three different cities across the United States. Since a convenience sample was used, results are not representative of each city. More specifically, we seek to test the following hypotheses, which are drawn from the aforementioned studies:

H1: Those of minority races, specifically non-Whites, were more likely to experience more frequent and longer power outages than Whites.

H2: Those of lower socioeconomic status were more likely to have experienced greater economic impacts, such as having thrown food away, and were less likely to receive assistance than those of higher status.

We decided to approach the research through a social vulnerability perspective to help identify potential factors. Social vulnerability shows that those of lower socioeconomic status and minority racial groups are more likely to experience greater impacts from a natural hazard due to lack of access to resources (Cutter et al. 2003; Adger 2006).

**II.) Case Study Sites**

This section provides a background of each of the three cities in our sample and how they compared to the 2018 American Community Survey (ACS) 5-year estimates (Table 1) and the distribution of household income in each study city (Table 2). We wanted to sample cities that had demonstrated diversity in demographics and different climates. The three cities selected represented these criteria as each has varying demographics and experience different hazards that can lead to power outages. Each city's sample is described in the subsequent subsections along with a brief discussion of the hazards that can cause power outages in each site.

**Table 1.** Comparisons between each of the samples from each city and comparisons to the 2018 ACS estimates.

| Demographic | Phoenix Sample (%) (n = 412) | 2018 ACS Phoenix Estimate (%) (n = 4,561,038) | Miami Sample (%) (n = 243) | 2018 ACS Miami Estimate (%) (n = 6,019,790) | Detroit Sample (%) (n = 251) | 2018 ACS Detroit Estimate (%) (n = 4,304,613) |
|---|---|---|---|---|---|---|
| White/Caucasian | 70.84 | 78.2 | 38.89 | 70.9 | 63.85 | 69.7 |
| Black | 5.78 | 5.3 | 17.52 | 21.4 | 16.15 | 22.3 |
| Indian | 1.2 | 2.2 | 3.42 | 0.2 | 1.92 | 0.3 |
| Asian | 7.95 | 3.7 | 5.98 | 2.5 | 5.38 | 4.1 |
| Native Hawaiian/Islander | 0.48 | 0.2 | 0 | 0 | 0.38 | <0.01 |
| Other | 1.92 | 6.9 | 3.0 | 2.9 | 3.84 | 1.2 |
| Hispanic | 9.16 | 30.5 | 33.76 | 44.2 | 3.08 | 4.3 |
| Non-Hispanic | 88.92 | 69.5 | 64.96 | 55.8 | 91.54 | 95.7 |

***A.) Phoenix, AZ***

Phoenix metropolitan area respondents were similar to the 2018 American Community Survey (ACS) 5-year estimates except for Hispanics being highly underrepresented (and Whites/Caucasians slightly underrepresented. Asians/Asian Americans were slightly overrepresented in our sample compared to the population estimate. Participants from the Phoenix sample (n = 412) were predominantly White or Caucasian (72%). We also had representation from many minority groups including Hispanic, Latino, Mexican-American, or Spanish (9.3%), Asian or Asian American (58%), Black or African American (5.5%), Middle Eastern and Native American or American Indian (1.5% each), and Native Hawaiian or other Pacific Islander (0.6%). A breakdown of the Phoenix sample in comparison with the ACS 2018 5-year estimates can be seen in Table 1.  81 respondents (24.4%) reported living with someone under the age of 6 and 52 respondents (15.57%) reported living with someone over the age of 64. Household combined income, of everyone in the home, was primarily between $20,000 and $79,999. The spread of household income represented from Phoenix can be seen in Table 2. A majority of participants own the property where they live (52.05%) while most of the remaining

**Table 2.** Distribution of household income from participants of each study site.

| Income Bracket | Phoenix Metro n = 402 | Detroit Metro n = 247 | Miami Metro n = 226 |
|---|---|---|---|
| Less than $5,000 | 1.49% | 3.54% | 1.21% |
| $5,000 to $9,999 | 2.24% | 2.65% | 3.64% |
| $10,000 to $14,999 | 2.24% | 3.98% | 4.45% |
| $15,000 to $19,999 | 4.73% | 4.87% | 6.07% |
| $20,000 to $39,000 | 15.17% | 21.68% | 18.62% |
| $40,000 to $59,999 | 23.13% | 19.47% | 10.93% |
| $60,000 to $79,999 | 16.17% | 16.81% | 17.81% |
| $80,000 to $99,999 | 8.96% | 11.95% | 13.77% |
| $100,000 to $119,999 | 11.69% | 5.75% | 8.91% |
| $120,000 to $199,999 | 8.71% | 3.54% | 9.31% |
| $200,000 and over | 1.74% | 2.65% | 2.02% |

participants rent their current home (40.96%).

Phoenix is prone to power outages due to extreme temperatures that exacerbate two factors. First, electrical infrastructure is exposed to these extreme temperatures, resulting in reduced performance and increased demand from consumers, which may lead to brownouts as a larger than average amount of electricity is used to power air conditioning units. Phoenix also experiences a monsoon season where thunderstorms can be accompanied by strong winds, which can lead to dust storms that result from these winds that can lead to power outages. Monsoons and accompanying hazards are common during the summer season.

***B.) Miami, FL***

Miami metropolitan area respondents were not as similar to the 2018 5-year ACS estimates with whites significantly underrepresented and Hispanics and Blacks or African Americans being slightly underrepresented. Asian/Asian Americans and Indians were slightly overrepresented in our sample. In Miami (n = 243), the two highest reported racial groups of our sample were White/Caucasian (38.89%) and Hispanics (33.76%). After Hispanics, Black or African Americans were the next highest (17.52%) and followed by Asian/Asian American (5.98%), and Indian (3.42%). There were no participants who reported either being Middle Eastern or Native Hawaiian/other Pacific Islander. A breakdown of the comparisons between the sample from Miami compared to the ACS estimates are shown in Table 1. 59 respondents (26.22%) reported living with someone under the age of 6 and 62 respondents (27.56 %) reported living with someone over the age of 64. Household income was primarily between $20,000 and $99,999. The spread of household income represented in our survey can be seen in Table 2. A majority of participants own the property where they live (56.83%) while most of the remaining participants rent their current home (36.42%).

Miami has a tropical climate that is known for isolated thunderstorms. Thunderstorms may produce damaging winds that can cause power outages. Miami is also unique in that hurricanes, and sometimes major hurricanes or a minimum category three storm on the Saffir-Simpson scale. Hurricanes can produce significant damage to infrastructure and can lead to longer power outages post-hazard.

***C.) Detroit, MI***

Respondents in the Detroit metropolitan area were similar to the numbers reported in the 2018 ACS estimates. Blacks/African Americans and Whites were slightly underrepresented and other racial groups (outside of the possible races provided by ACS) were slightly overrepresented in our sample (n=251). Detroit's two highest reported racial groups were White/Caucasian (66.14%) and Black/African American (16.73%). Asians were the next highest (5.98%) followed by Middle Eastern (3.19%) with the remaining groups (Native American, Native Hawaiian/Pacific Islander, Hispanic, and Other) each representing under 3% of the sample. A breakdown of the comparisons between the sample from Detroit compared to the ACS estimates are shown in Table 1. 61 respondents (26.29%) reported living with someone under the age of 6 and 33 households (14.16%) reported living with someone over the age of 64. Household income was mostly between $20,000 and $79,999. The spread of household income represented in our survey can be seen in Table 2. A majority of participants own the property where they live (65.98%) while most of the remaining participants rent their current home (27.34%).

Detroit is the only city of the three study sites where winter weather can cause power outages. Ice can accumulate on power lines and cause them to break whereas Phoenix and Miami do not have to worry about ice storms frequently occurring. Detroit can also experience severe weather, similar to the other study cities, that can produce damaging winds and cause power outages.

## III.) Methods

### *A.) Survey*

To gain a broader perspective on household-level experiences during power outages, we deployed across three major cities in the United States: Detroit, MI; Miami, FL; and Phoenix, AZ. The survey was hosted in Qualtrics and deployed through Amazon's Mechanical Turk (MTurk). MTurk is a crowdsourcing platform that facilitates the completion of a wide suite of tasks by a portion of the public that has opted-in to serve as workers. MTurk surveys have become a reputable method of conducting surveys in the social sciences literature as scholars have demonstrated their utility, accuracy, and internal reliability despite concerns over sample biases (Bates et al. 2013; Buhrmester et al. 2013; Paolacci et al. 2010). In the case of survey research, the MTurk service enables administrators to deploy surveys electronically that can be completed by MTurk workers, who serve as survey participants, for compensation.

The survey was disseminated in two waves, early February 2020 and again in early March 2020, that each provided a different compensation amount. The first wave compensated participants $0.80 for their time if they were eligible and completed the full survey. To increase the sample size, responses completed in the second wave were compensated at $1.60. In total, 896 participants across the three cities completed the survey. This sample is not representative of the U.S. population. However, the sample from Phoenix was the closest to being generalizable to the city's demographics; Miami's and Detroit's samples were not generalizable due to a small sample size. To achieve generalizability in all three cities, each city needed 385 responses for a 95% confidence level with a 5% margin of error.

Once participants began the survey, they were presented with an overview of the survey, how their responses would be utilized, and asked for their consent (if able to) to proceed. Within the survey, there were five sets of questions relevant to the research that included multiple-choice questions, multiple answer questions, and short open-ended responses. Potential participants were first asked a series of questions that served as filtering criteria to determine if they qualified to complete the remainder of the survey. Three questions served as the filtering criteria. The first filter was to eliminate all participants that were not within the three target cities. Participants were provided with a list of major cities within their respective states. Participants had to select “Phoenix” for the Arizona version, “Miami” for the Florida version, or “Detroit” for the Michigan version. The next filtering question asked if they lived at their current residence for more than six months of the year. Participants had to select “Yes” to this question to be eligible for the full survey. The last filtering question if participants had experienced a power outage at their current residence within the last 5 years. To continue through the survey, participants must have responded “Yes” to experiencing a power outage to be eligible to receive the full compensation amount. If they answered “No” to experiencing a power in the last 5 years and met the other two qualifications of the survey, they would be directed to a shorter version of the survey (11 questions) that asked about generator ownership, the current financial situation of the household, and basic demographic information (Q105-Q115 in Appendix B, listed before Q9 and the full version of the survey). If participants met all three criteria, they then could complete the full version of the survey. After completing the survey, participants received a randomly generated four-digit number from Qualtrics to enter into MTurk that made them eligible for compensation.

In the full version of the survey (see Table 3), the first set of questions focused on generator ownership and maintenance, carbon monoxide ownership and maintenance, and the distance the generator was running relative to the residence. Questions probing these adaptive resources helped determine the level of adaptive capacity that participants had for future power outages. Participants were asked about the use of these resources during their longest power outage, and if they did not use certain resources, why. Additionally, if participants owned a generator and used it during their longest power outage, three additional questions were asked related to the relative distance their generator was from their home and if the home had a carbon

**Table 3.** The structure of the survey qualified participants was able to complete.

| Section | Variables Probed | Number of questions |
|---|---|---|
| 1 | Generator ownership and maintenance, carbon monoxide ownership and maintenance, distance generator was running relative to residence | 9 |
| 2 | Power outage frequency, thrown away food, assistance provided, organizations that provided assistance | 5 |
| 3 | Most recent outage, month and year of most recent power outage | 2 |
| 4 | Longest power outage length, month and year of the longest outage, leaving home and where they went, communication of the outage, difficulty accessing food or water, financial burden to replace food, reliance on a medical device | 15 |
| 5 | Racial/Ethnic background, personal and household income, children or elderly in the home | 8 |

monoxide detector. The latter questions were aimed at asking if those who used generators during their longest outage were aware of safe practices since it is possible for the fumes produced from the generator to travel to the inside of the home, posing a serious threat to occupant's health and safety (FEMA 2018). From the second set of questions, participants were asked about their previous power outage experiences. Participants were asked approximately how many power outages they experienced at their current residence within the last five years if they had to throw away food because it spoiled during a power outage, and what assistance if any, they received during a power outage. Assistance could have been from local churches or organizations or national-level or government organizations such as the American Red Cross or FEMA.

The third set of questions asked about the most recent outage experienced and then asked approximately when it occurred.

The fourth set of questions probed participants lower-level questions about their household's experience during their longest power outage, to the best of their recollection. This section was crucial in answering the research questions and asked participants questions about how they were affected during the outage and how they managed their situation until power was restored. Questions in this section pertained to if participants left their residence to go somewhere else until power was restored, such as a local shopping center, hotel, or a close friend or relative's house and how long they were inside their residence without power. Additional questions in this section pertained to the communication of the outage, if participants were notified the outage would occur, if they used someone else's generator, if the outage caused difficulties accessing food or water, how much of a financial burden it was to replace spoiled food, and if the participant or anyone within the home relies on a medical device that is dependent on electricity. If so, then participants would be asked how they were able to cope without the necessary medical equipment during their longest power outage.

The final set of questions in the survey queried participants about their general living situation, in terms of who lives within the house ("Is anyone living at your primary address younger than 6 years old?" and "Is anyone living at your primary address older than 64 years old?"), challenges to purchasing basic life essentials, the household's current financial situation, and basic demographic information. There was also a comments section where participants may add notes that could augment some of their responses, add context to unusual answers within the survey, or add further explanation regarding their situation.

A full version of the survey is available, with variable coding and labeling schemes, in Appendix B.

### *B.) Coding and Data Cleaning*

Once all viable participants completed their surveys, the results were extracted from Qualtrics to a Microsoft Excel CSV file. When downloading the results from Qualtrics, the responses were displayed by their numerical values to allow the data to be imported into the statistical analysis software, R Version 1.1.463. Before the analysis, the data needed to be cleaned as most questions had options that included "Don't know" and "Prefer not to answer"[1]; these responses were removed from all analyses. There were also instances where the coded values for responses, especially those with incremental value questions (such as income) and

[1] Removing these responses did not alter the results of the data as few participants selected this option. Only one question was affected by removing these responses, "From which organization(s) did you receive assistance? Please check all that apply.".

time-related questions. Choices were either not in order from least to greatest or the time intervals were not evenly distributed.

### *C.) Analysis*

The analysis comprised of descriptive statistics, correlations[2], and difference of means tests (Kruskal-Wallis), for each of the selected sites. Descriptive statistics consisted of reporting the modes for any time-related questions, such as the number of power outages experienced, income for both the participant and their household, and the length of the participant's most recent and longest power outages. Utilizing descriptive statistics helped contextualize the experiences provided by participants in intra-city and inter-city comparisons and provided a more in-depth examination of the relationship between demographic information and self-reported impacts of power outages. We also used correlation tests to look at the relationships between the independent variables.

After the data were cleaned, some variables needed to be recoded into a binary response system that would allow for Kruskal-Wallis tests to be conducted. From the full survey, we extracted 20 variables for further analysis: race (white/non-white), income (low/high), experiencing a power outage (yes/no), number of outages (less than 10/more than 10), owning a generator (yes/no), owning a medical device (yes/no), living with children (yes/no), living with elderly (yes/no), purchasing a generator for future outages (yes/no), how long a participant owned their generator (less than one year/more than one year), leaving home during their longest outage (yes/no), receiving assistance (no help/help), struggle to afford essentials (yes/no), awareness of the longest power outage (aware/not aware), recent outage length (less than one day/more than one day), longest power outage (less than one day/more than one day), length of time at home (less than one day/more than one day), struggle to afford essentials (yes/no), have thrown away food because of a power outage (yes/no), and using their generator during the longest power outage (yes/no). With the yes/no binary system, the only recoding that needed to be done was to remove any responses of "Don't know" and "Prefer not to answer".

[2] Most independent variables did not correlate with each other. The variables that showed strong correlations (coefficient values greater than 0.75) were between owning a generator, owning a generator for more than one year, and purchasing a generator for future outages. Moderate correlation values were found between struggling to afford essentials and income in Detroit and Phoenix (coefficient values between 0.3 and 0.4).

## IV.) Results

The results section first describes each city sample followed by the most frequent answers to selected survey questions. This section intends to first show how power outages vary between each city through descriptive statistics. Then, the second section of the results looks at the results of the Kruskal-Wallis tests and the relationships that emerged

### *A.) Descriptive Statistics*

*1.) <u>Power Outage Preparedness and Coping Strategies</u>*

A majority of participants across all three study cities did not own a generator (Phoenix = 85.9%, Miami = 58.4%, Detroit = 73.1%)[3]. Those that reported owning a generator have owned it for at least one year (Phoenix = 86.96% , Miami = 89.61%, Detroit = 85.49%) and primarily perform maintenance at least once per year (Phoenix = 37%, Miami = 46.8%, Detroit = 42.6%). Those that owned a generator also reported purchasing their generator to use for future power outages (Phoenix = 71.7%, Miami =100% , Detroit = 85.5%).

Responses to questions asking about assistance received, owning a medical device, and managing personal conditions were similar across the study cities. Assistance, whether it was financial or resources such as food and water, was not provided to many participants in all cities (Phoenix = 82%, Miami = 45.8%, Detroit = 80.7%)[3]. Few participants relied on a medical device in all three cities (Phoenix = 6.9%, Miami = 12.6%, Detroit = 6.9%) and most do not live with someone that relied on a medical device (Phoenix = 93.1%, Miami = 80.2%, Detroit = 92.3%). Those that relied on a medical device managed their condition during their longest power outage differently across the three cities. Those in Phoenix and Detroit mostly waited for power to be restored (Phoenix = 32.1%, Detroit = 30%) or went somewhere that had power (Phoenix = 25%, Detroit = 35%). In Miami, those who relied on a device primarily called for help from a friend or relative (31%) or went somewhere else with power (25%).

A majority of participants from Phoenix and Detroit were not aware they would lose power before their longest power outage (Phoenix = 84.4%, Detroit = 80%). Those in Miami were more aware they would lose power and were notified the day of (19.3%), the day before

[3] The large difference in responses could be because of Miami experiencing hurricanes that lead to more prolonged power outages. Thus, residents in Miami are more likely to have resources, like a generator, and are more likely to receive assistance due to the damages that hurricanes can cause.

(17.6%), one to three days before (20.3%), or four or more days (18.7%) before they lost power. Those that were aware that their longest power outage was going to happen found out this information through traditional news (Phoenix = 28.9%, Miami = 33.8%, Detroit = 28.6%), social media (Phoenix = 25%, Miami = 10.1%, Detroit = 14.3%), or from meteorologists (Phoenix = 15.4%, Miami = 33.8%, Detroit = 28.6%).

*2.) <u>Power Outage Experiences</u>*

Most participants, regardless if they qualified, reported experiencing a power outage in the last five years (Phoenix = 83.5%, Miami = 89.8, Detroit = 91.5%). Participants in all three cities reported experiencing one to five power outages (Phoenix = 77.2%, Miami = 45.5%, Detroit = 62.7%) or five to ten power outages (Phoenix = 16.4%, Miami = 32.3%, Detroit = 23.4%) at their residence within the last five years. The most recent outage length reported by participants from Phoenix and Miami were mostly one to six hours (Phoenix = 53.57%, Miami = 37.2%) or less than one hour (Phoenix = 31.3%, Miami = 20.7%). Detroit had slightly longer power outages recently with more participants reported their most recent outage lasting one to six hours (39.5%) or six to twelve hours (17.2%). For the longest reported power outage length, responses were less similar than previous questions. Phoenix participants reported the longest power outage lasted one to six hours (55.1%) or less than one hour (17.4%). Miami also had participants report their longest outage lasted one to six hours (20%) but slightly more indicated their longest outage lasting three to seven days (21.1%). Detroit, similar to Phoenix and Miami, had more participants reported their longest outage times of one to six hours (24.5%), but like Miami, more reported longest outage lengths of one to three days (30.9%).

During the longest reported power outage, participants in all three cities noted they were primarily inside their homes for one to six hours (Phoenix = 57.2%, Miami = 25.1%, Detroit = 30%). Miami participants had also reported being at home for three to seven days (23.0%) and, similarly, Detroit had participants state they were in their home for 12 to 24 hours and one to three days (21.03% for each of the two responses). Those that did leave their home during their longest reported outage primarily went to a family’s, friend’s, or neighbor’s house that had power (Phoenix = 46.6%, Miami = 60.3%, Detroit = 63.8%), movie, mall, or other commercial space (Phoenix = 28.5%, Miami = 14.1%, Detroit = 9.6%), or stayed at hotel or motel where they paid for temporary lodging (Phoenix = 11.2%, Miami = 14.1%, Detroit = 14.9%). A majority of participants that owned a generator used it during their longest power outage in all three cities (Phoenix = 67.4%, Miami = 85.7%, Detroit = 83.9%). Those that used their generator reported their generator was either somewhere next to their home to 10 feet away (Phoenix = 38.7%, Miami = 48.5%, Detroit = 60.8%) or 11 to 24 feet from their home (Phoenix = 32.3%, Miami = 27.3%, Detroit = 19.6%). Some participants that owned a generator did not use it during their longest power outage. Reasons why their generator was not used were identical across the three cities and included the power outage was brief, they did not own their generator at the time of their longest power outage, their generator was too loud, their generator was not working (especially in Miami), and they wanted to save on fuel for real emergencies.

Access to food and water because of the longest outage did not become more difficult in Phoenix and Detroit (75.5% and 63.4%, respectively), but did become more difficult in Miami (55%). Participants reported they were able to use water from primary sources, such as taps, sinks, and showers (Phoenix = 78.1%, Miami = 66.1%, Detroit = 77.3%). Other sources of water that participants used for drinking primarily came from bottled water that was already purchased prior to losing power (Phoenix = 62.8%, Miami = 48.6%, Detroit = 52.6%) or bottled water purchased after losing power (Phoenix = 15.7%, Miami = 29.5%, Detroit = 25.4%). Overall, power outages caused a financial burden to some in Phoenix and Miami, but fewer people in Detroit.

### *B.) Statistical Analysis*

To understand how race and income influence power outage length and frequency, a Kruskal-Wallis difference of means test was used to determine in what cities these relationships were statistically significant. A compilation of all statistically significant relationships and independent and dependent associations tested can be found in Tables 4, 5, and 6. Each subsection that follows describes the significant associations that each dependent variable had with independent variables. First, the results from the relationships that tested our hypotheses are detailed, specifically, those related to race and income, see H1 & H2.

#### *1.) <u>Power Outage Length and Duration</u>*

Experiencing a power outage was a primary dependent variable for our research. However, after conducting Kruskal-Wallis tests with each of the independent variables, no statistically significant relationships could be established. A visualization of the results from this

**Table 4.** Results from Kruskal-Wallis tests with variables measuring power outage frequency and duration.
P = Phoenix, M = Miami, D = Detroit; + = Anticipated result, - = Not anticipated result
* = p < 0.05, ** = p < 0.01, *** = p < 0.001

| | Experience power outage | Longest outage length | Number of Outages | Recent Outage Length |
|---|---|---|---|---|
| **Income** | | P-* | D+* | P-* |
| **Live with children** | | | | |
| **Live with elderly** | | | | |
| **Own generator** | | | P+*** | |
| **Own Medical Device** | | | P+** | |
| **Race** | | P+**<br>D+** | | P+**<br>D-*** |
| **Struggle to afford food** | | | D+** | |

section can be seen in Table 4.

Power outage frequency was only supported in Detroit where those of lower-income were more likely to experience more frequent power outages ($p < 0.05$). Results were not the same in Phoenix and Miami. Race was not significantly associated with outage frequency in any of the study cities.

Recent outage length had significant associations with race and income. In Phoenix, higher income was associated with experiencing longer outages during their most recent outage ($p < 0.05$). Non-Whites in Phoenix were more likely to experience longer outages recently ($p < 0.01$), this was the opposite in Detroit with Whites reporting longer outage times during their most recent outage ($p < 0.001$). No significant associations were found in Miami that related to either race or income.

Similar relationships were found with the relationships with the longest reported outage length. In Phoenix, those of lower-income reported longer outage times during their longest power outage ($p < 0.05$). Non-Whites were also more likely to report longer outage times during their reported longest power outage in Phoenix and Detroit ($p < 0.01$ in Phoenix; $p < 0.001$ in Detroit).

2.) *Power Outage Impacts*

**Table 5.** Results from Kruskal-Wallis tests with dependent variables measuring power outage impacts. P = Phoenix, M = Miami, D = Detroit; + = Anticipated result, - = Not anticipated result
* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

| | **Length of time at home** | **Not receiving help** | **Have thrown food away because of an outage** |
|---|---|---|---|
| **Income** | P+* | | D+* |
| **Live with children** | D+** | M+** | P+***<br>D-** |
| **Live with elderly** | D+* | | |
| **Own generator** | D+* | D-** | P-***<br>M-* |
| **Own generator (> 1 year)** | | D-* | P-***<br>M-* |
| **Own Medical Device** | | M+***<br>D+*** | P+* |
| **Purchase generator for future outages** | | D-* | P-**<br>M-* |
| **Race** | P+**<br>D+*** | M+* | D+** |
| **Struggle to afford food** | | P+** | P+*<br>D+*** |

Phoenix and Detroit had significant associations between the primary independent variables and dependent variables that probed participants on how they were impacted during their longest power outage. First, shorter reported lengths of time at home in Phoenix were associated with those of lower-income ($p < 0.05$). Additionally, non-Whites in Phoenix and Miami reported being at home for longer periods during their longest reported power outage ($p < 0.01$ in Phoenix; $p < 0.001$ in Detroit). Results from Miami did not indicate any significant relationships. The results of these tests can be seen in Table 5.

Receiving assistance was only significantly associated with race and income in Miami. Those who reported being non-White were more likely to not receive assistance during their longest power outage ($p < 0.05$). Neither Phoenix nor Detroit had significant associations. There were also no significant associations between income and receiving assistance during the longest power outage in these cities.

Having thrown away food because of a power outage was only associated with race and income in Detroit. Those who reported being of lower-income had thrown away more often because of an outage than those of higher income ($p < 0.05$). Minorities were also more likely to report that they had thrown away food because of a power outage ($p < 0.01$). No significant associations emerged from either Phoenix or Detroit.

*3.) <u>Coping Strategies</u>*

While awareness of the longest power outage and the likelihood of participants leaving their residence were not dependent variables of interest in answering our hypotheses, there were significant relationships that emerged. Table 6 shows these findings.

Awareness of the longest power outage occurring was associated with many independent variables, especially owning a medical device. Owning a medical device was associated with greater awareness of the longest power outage occurring in all three study cities ($p < 0.01$ in Phoenix and Miami, $p < 0.001$ in Detroit). Owning a generator was also associated with greater awareness in Phoenix ($p < 0.001$) and Detroit ($p < 0.05$). Those who reported being White/Caucasian were less aware of their longest power outage in Phoenix ($p < 0.001$). Income was not a significant variable with awareness in any city.

Leaving home during the longest power outage was associated with independent variables in Detroit and Miami, but not in Phoenix. Those of lower-income were more likely to leave home during their longest power outage in Detroit ($p < 0.01$). Those of minority races were more likely to leave their residence during their longest reported outage in Miami ($p < 0.05$).

**Table 6.** Results from Kruskal-Wallis tests with dependent variables measuring coping strategies.
P = Phoenix, M = Miami, D = Detroit; + = Anticipated result, - = Not anticipated result
* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

| | **Being aware of the longest power outage** | **Leave home during the longest outage** |
|---|---|---|
| **Income** | | D+** |
| **Live with children** | | M+* |
| **Live with elderly** | M-* | |
| **Own generator** | P+***<br>D+* | |
| **Own Medical Device** | P+**<br>M+**<br>D+*** | |
| **Race** | P-*** | M-* |
| **Struggle to afford food** | | D+** |

## V.) Discussion

### *A.) Summary of Findings*

Our initial hypothesis for this research was that non-White participants were more likely to experience longer and more frequent power outages and those of lower socioeconomic status were more likely to experience greater economic impacts, having thrown away food and not receiving assistance. Race was an independent variable associated with greater power outage frequency and duration in Phoenix and Detroit, but not in Miami; thus H1 was not supported. Income was expected to be strongly associated with economic impacts, but the results did not support this hypothesis either, H2. Thus, demonstrating that income is also not a universal variable to examine when determining the potential impacts of power outages.

In formulating our hypothesis, we wanted to test how indicators that have been proven to increase the impacts of hazards (e.g., hurricanes, heat) influenced household power outage experiences. However, when considering the secondary impacts of natural hazards, our research demonstrates that social vulnerability indicators do not fully explain why certain populations experienced longer and more frequent power outages. Therefore, when preparing for hazards that can lead to extended power outages, the same indicators that are used to identify where the greatest impacts caused by natural hazards are not the same indicators that should be used when identifying who will be the most affected by power outages.

Some results were unexpected and variables that were strongly associated with power outage impacts are not among those typically considered in social vulnerability analyses. When examining the amount of assistance given to the public because of a power outage, the results were surprising when we saw that most people were not receiving help. This finding might be related to the fact that their most recent outage was between 1 and 6 hours in each city. The most likely reason little help is being given is that these outages are short-lasting. Owning a medical device was more prevalent in statistically significant relationships with dependent variables, especially with the awareness of a power outage. Those who owned a medical device were more likely to be aware of their longest power outage; this relationship was statistically significant across all three study cities. Additionally, those who owned a generator were more likely to have thrown away food because of an outage. Seeing this relationship may mean that people bought their generator because they had previously had to throw away food that spoiled because of a power outage.

### *B.) FEMA Guidance and Recommendations*

Shorter power outages present a cause for concern for those who struggle to afford essentials. According to guidance from FEMA, they recommend that for long-lasting power outages to keep all refrigerators and freezers closed. Refrigerators can store food for up to four hours and freezers can store food for up to 48 hours during a power outage (FEMA 2018). Any food that has been exposed to temperatures above 40°F for more than 2 hours should be discarded or if the food has an unusual odor, texture, or color (FEMA 2018).

FEMA's guidance also recommended that generators should be located at least 20 feet from the home when operating. However, a majority of participants from all three cities had their generators less than ten feet away from their home. Operating a generator this close to a home increases the risk of negative health outcomes, such as carbon monoxide poisoning. Additional messaging is needed to inform people of safe generator practices to reduce the risk of exposure to carbon monoxide poisoning.

### *C.) Implications, Limitations, and Opportunities*

There are many opportunities for this work to be expanded. Future work could augment this research by examining the spatial relationships of participants to sites that are high restoration priority, such as critical services (hospitals, police, fire departments, etc.) to determine if living near these sites influence the length and frequency of power outages. Additionally, work could also expand on how living in rural, suburban, or urban areas affects power restoration times. Lastly, although this was not the intention of our research, examining whether a male or female head of household or various family structures influence power outage frequency or duration.

Limitations with this work mainly came from sample sizes and the composition of the sample from each city. Significance was more easily obtainable for some questions as, depending on the response choices, some were able to respond to questions that others did not see. For instance, fewer people owned a generator; therefore, fewer people were able to answer questions about generator maintenance and using their generator during their longest power outage. Also, the samples from each city were not completely representative of the 2018 ACS 5-year estimates. However, we were not able to control who participated in our survey so that generalizability could be achieved.

The implications of this work are relevant, especially given the current political climate that exists at the time of writing this work, with the Coronavirus pandemic and the heightened social unrest due to events that occurred in early June 2020. While income did not prove to be as significant as expected, race was a highly prevalent variable that significantly influenced many dependent variables. As power outages are expected to become more frequent and last longer due to the potential impacts of the future climate, addressing the inequalities of outage length due to race is vital. Therefore, response and recovery organizations need to ensure those of minority racial groups are given the necessary assistance to reduce the personal and financial impacts that power outages may cause.

## VI.) Conclusions

In this work, we surveyed 896 participants in 3 major cities across the United States (Detroit, MI; Miami, FL; Phoenix, AZ) to understand household experiences during power outages and what factors influence the frequency, duration, and impacts of power outages. The hypotheses for this research were that participants of minority demographics, non-Whites, were more likely to experience more frequent and longer power outages and those of lower socioeconomic status experienced greater economic impacts because of previous power outages. Race was associated with a few of the dependent variables in Phoenix and Detroit and did not support our hypothesis, H1. Also, income was not as strongly associated as initially hypothesized as being of lower socioeconomic status did not affect having thrown food away and receiving help, thus not supporting H2.

Other variables that were not initially hypothesized to influence power outage impacts were identified. Owning a medical device was associated with greater awareness of the longest power outage occurring, with high levels of statistical significance across all three study cities. Owning a generator was also significant with many variables relating to power outage impacts, specifically throwing away food because of an outage, regardless of how long they owned their generator. Those who owned a generator were more likely to have thrown food away because of a power outage.

Impacts from power outages on both people and infrastructure can be reduced for future events. Increased mitigation funding allocated towards improving infrastructure would decrease the risk for infrastructure to fail. A portion of these investments can be put towards burying power lines to reduce exposure in high-wind prone areas, especially areas where hurricanes make landfall. Before events where power outages are likely to occur, actions can be done to increase the public's awareness such as safe generator practices, providing free CO detectors, and providing consistent information about when power will be restored.

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## Conclusions

The overall goal of this thesis was to understand the social impacts of outages and investigate factors that could influence power outage frequency and duration. In the first chapter of this thesis, a systematic literature review was conducted to understand how power outages impact society. Through this review, 45 relevant papers were identified from a combined search that yielded 762 articles. Papers that were included observed the impacts of power outages that occurred after significant natural hazards, including Superstorm Sandy, or a result of failures in electrical infrastructure, such as the 2003 Northeastern United States blackout. Three themes emerged from this review that showed how power outages impact people, including health impacts, populations of concern, and criminal activity. Health impacts included CO poisoning, because of unsafe generator use (Wrenn & Conners 1997; Riddex & Dellgar 2001; Musciatello et al. 2006; Van Sickle et al. 2007; Fife et al. 2009; Call 2010; Johnson-Arbor et al. 2014; Schnall et al. 2017) increased hospital and emergency department visits (Baer et al. 2011), and increased working hours and stress on healthcare workers (Klein et al. 2007;). Populations of concern were identified and include children (Fife et al. 2009; Schnall et al. 2017), non-English speakers (Wrenn & Conners 1997; Burger et al. 2013; Schnall et al. 2017), minority demographics (Muhlin et al. 1981; Lin et al. 2016), the elderly (Anderson & Bell 2012; Klinger et al. 2014; Gotanda et al. 2015; Lin et al. 2016; Chakalian et al. 2019; Rubin & Rogers 2019) those living in rural areas (Call 2010; Román et al. 2019), and those of higher socioeconomic status (Lin et al. 2011). The criminal activity was the third theme that emerged from this review. Non-violent crimes increased during prolonged power outages (Rubin & Rogers 2019). However, while the public sector can provide this assistance, it only serves as a temporary fix; once this relief expires, the crime rate increases (Rubin & Rogers 2019). Consistent communication throughout the event should be a top priority for all officials as consistent communication decreased levels of anxiety during power outages. Additionally, acts of altruism increased and people were more likely to assist others if needed (Lemieux 2014).

The second chapter of this thesis utilized a survey that was deployed through Amazon's Mechanical Turk that targeted three major cities across the United States (Detroit, MI; Miami, FL; Phoenix, AZ) to understand how households are impacted by power outages. From the three cities, 896 participants qualified for the full version of the survey and received compensation for their work. Through the survey, race was found to be significant variables in influencing power outage duration in Phoenix and Detroit, but not in Miami. Also, income was not associated with having thrown food away because of an outage and not receiving assistance as initially hypothesized. These findings do not support, conclusively, that utilizing social vulnerability indicators where the greatest impacts of power outages are most likely to occur. Owning a medical device was significant with the frequency and duration of power outages and with an awareness of the longest power outage. Owning a generator was also significant in relationships with dependent variables. These independent variables also did not significantly influence relationships with most of the dependent variables. Overall, the initial hypothesis regarding minority demographics experiencing greater impacts because of power outages was not supported. The second hypothesis regarding those of lower-income experiencing greater economic impacts was also not supported.

This thesis contributes to knowledge by producing the first review that examines exclusively academic literature on the social impacts of power outages. Klinger et al. (2014) was the most similar review to the one completed for this thesis. However, the review completed by Klinger et al. utilized only two years (2011-2012) of academic literature for their review and explored power outage impacts caused by extreme events exclusively from the health perspective. The review within this thesis utilized 42 years of peer-reviewed literature and expanded the health perspective.

The survey component used a new methodology that has not yet, to the best of the author’s knowledge, been used to obtain information about households’ experiences with previous power outages. Additionally, understanding household experiences across a variety of major metropolitan areas have not yet been studied in great detail at the time of this thesis. A few studies have done similar studies to the one produced in this thesis, however, these studies are either limited in spatial coverage (Chakalian et al. 2019; Mitsova et al. 2019) or findings cannot be generalized due to obtaining a small sample size (Kosa et al. 2012; Chakalian et al. 2019). Kosa et al. (2012) was similar but focused exclusively on the elderly population’s preparedness for future power outages.

While completing this thesis, there were a few aspects of the research that would be changed for future work. First, before reading any of the titles or abstracts of the search results, categories would be created to classify each entry to show whether the article examined a hazard or the hazard and the impacts of the power outage that followed (single hazard vs. multiple hazards). Establishing a plan for the additional classification schemes would have saved many hours that were spent going through the final list of literature multiple times to do so (essentially creating all of the possible categories before reading through the final list of literature and not doing so multiple times after discovering what additional data was needed while writing the review). Instead of using inductive themes, deductive themes would have been used based on previous reviews to create the classification scheme of the articles that qualified for the review.

For the survey, some aspects of both the survey and survey dissemination would be changed. Within the survey itself, additional questions relating to the type of area participants lived (rural, suburb, or urban), and how their outage occurred (to the best of their memory by weather or event or a sudden outage) would be asked. When analyzing the data, it became apparent that one question was not the same in both versions, asking if anyone in the participant's home relies on a medical device. Since this question was not the same, the question in both versions could not be combined within the data analysis. Primarily, results from the qualified version were used in the analysis, but if a question was asked in both the short and full versions of the survey, the results were combined for the analysis. The number of responses from the short

Considering survey dissemination, there are other possible methods for distributing the survey. Amazon's Mechanical Turk (MTurk) could still be utilized as a method of recruiting participants. However, the possibility exists for the same survey to be hosted on multiple sites as Qualtrics has a feature that tracks IP addresses to ensure the same participant does not attempt to complete the survey more than one time. However, hosting the survey on a platform that requires compensation for participants and on another platform simultaneously that does not require compensation seems ethically unfair. If this were research would be repeated, the survey would be hosted on platforms that either do require compensation or do not require compensation, not a mix of the two (i.e. MTurk and SurveyMonkey).

Future literature reviews would be able to compare findings within the review herein to show how research has expanded on the social impacts of power outages. Given the current increasing amount of published research, there will be more articles available for the next iteration of this review with new research to elaborate on the findings presented and fills new gaps within the literature.

For the survey component, future work should examine the relationship between housing community types (urban, rural, and suburban) and how it influences power outage length and frequency. Within rural areas, the literature suggests that these areas are prone to experience longer power outages and longer restoration times because of the scattered nature of infrastructure compared to urbanized areas (Call 2010; Román et al. 2019). Gender was not included in this research as the focus was on households. Future work should look at whether male or female heads of households influence power outage frequency and duration.

The results revealed there are more systematic racial injustices to what is already known about hazard response and recovery. Not only do those of minority demographics experience greater impacts from natural hazards because of a lack of resources, but they also experience greater impacts from secondary hazards, such as power outages (Cutter et al. 2003; Adger 2006). To further address this issue, organizations that assist must continue to focus on areas with higher demographic minorities as they will experience greater impacts from future hazards. Additionally, this thesis also informs policy by demonstrating that despite efforts done to reduce hazard impacts in vulnerable locations, a great need exists to ensure that the assistance that is provided to affected areas is equitable – not equal – distributed.

While there is an emphasis to prepare for the impacts of the event with improved messaging and communication, there tends to be a lack of understanding of what will happen post-hazard. During this time, electricity is likely unavailable so access to information can be challenging, demonstrating the need for redundant communication methods so those that lose power have access to important information during the power outage (Klein et al. 2007). This loss of communication can create an additional layer of vulnerability for some households, but not all households experience this challenge.

This thesis has expanded on the work done by Klinger et al. (2014), Kosa et al. (2012), Chakalian et al. (2019), and Mitsova et al. (2019). The work from Klinger et al. focused on how power outages impact health and healthcare because of natural hazards. The authors explored all types of sources including media pieces to demonstrate the various impacts experienced. Whereas this thesis not only explores health impacts but also expands on this topic to include the populations of concern and the potential criminal behavior that may occur due to prolonged power outages.

The survey portion of this thesis expanded on the survey and interview work previously published by Kosa et al. (2012), Chakalian et al. (2019), and Mitsova et al. (2019). Kosa et al. focused on the elderly population across the United States, with no geographic focus and with a subset of their initial survey sample, only 290 people over 60 years of age. This thesis builds upon this work by not including all populations that were able to give consent for this research by Kosa et al. (2012). Chakalian et al. (2019) utilized semi-structured interviews to demonstrate how 42 people across two counties in western Florida impacted by Hurricane Irma in 2017 coped with the power outage that, for some, lasted up to seven days. This thesis expanded on this work by utilizing multiple cities in varying regions across the United States to better capture experiences in different geographical and political contexts. The authors analyzed their data using qualitative data analysis techniques to arrive at their conclusions whereas this thesis utilized quantitative methods for the analysis of the survey data. Finally, Mitsova et al. (2019) did similar work to that of Chakalian et al. (2019) but used a larger sample size, 989 households, from western and southern Florida to examine the recovery process 8 months after Hurricane Irma made landfall. The authors utilized logistic regression modeling to demonstrate that many variables are significant indicators of disaster recovery when related to age and race. These variables included physical damage to property, disruption of infrastructure services, and other factors (i.e., homeowner’s or renter’s insurance coverage, receiving disaster assistance and loss of income) (Mitsova et al. 2019). This thesis expands on this work by Mitsova et al. similarly to Chakalian et al. as diverse locations that are affected by different hazards, and affected differently, were used. Additionally, the timing of the survey conducted for this thesis was not after a natural hazard and was closed before the massive spike of Coronavirus cases in the United States. Responses were no longer accepted once multiple state-wide shutdowns were announced to remove any potential influence caused by the pandemic from participants’ responses.

The future climate will possess many issues for both infrastructure and people alike. While we understand what adaptations are necessary to reduce these impacts, people will ultimately be impacted by any failures that occur within the highly interdependent electrical grid system. Investments are needed to increase the robustness of electrical infrastructure so that the number of future electrical disturbances may be reduced and the cascading effects that result from future failures are less crippling. The electricity demand will increase given the expected increase in global temperatures and the growing population, specifically in the United States. Without planning for the potential futures that may come to fruition, catastrophic consequences may result; the time to act is now.

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APPENDIX

A.) List of all literature reviewed in the systematic literature review.

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Abir et al. | 2013 | 81 dialysis centers that responded | Semi-structured interviews | | X | | | Hemodialysis centers are impacted by power outages.<br>Centers need to have alternative sites and plans available to direct patients who need treatments to other facilities.<br>Most centers already have plans included in existing emergency plans. |
| Anderson & Bell | 2012 | Mortality data, temp and dewpoint data, AQ data to model blackout days | Gen. Linear Model with data from 1987-2005 to estimate mortality risk and possible confounders | X | X | | | Mortality increased for both accidental and non-accidental deaths during the 2003 Northeastern United States blackout.<br>Understanding power outage impacts on health is relevant, given the increased demand for electricity and the anticipated impacts of climate change on the electric grid. |
| Arya et al. | 2016 | 35 pharmacies | Surveys | | X | | | Those dependent on pharmacies for medicine, pharmacies that do not have a backup generator are vulnerable to power outages after extreme events.<br>Pharmacies that are physically vulnerable to hazard impacts need to prepare to provide care and be able to redirect patients and customers to alternative locations if backup supplies are running low or the location does not own a generator.<br>Community pharmacists are important stakeholders when discussing community resilience in New York City in preparedness strategies. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Baer et al. | 2011 | 241 CO cases confirmed by chart review in the state of Washington | Ran detection algorithms to find health events associated with the CO outbreak. Also used spatial and spatiotemporal scan statistics to find geographic areas most affected by the CO poisoning event | X | X | | | Carbon Monoxide cases increased after severe weather events where widespread power outages occurred. Gastrointestinal issues also increased due to food spoilage. |
| Becker et al. | 2012 | 126 CO poisonings | Case Study? | | X | | | Of the 126 Carbon Monoxide-related cases identified, 77% were related to generator use with 43% of generators being located outside the home but next to a window. Minority demographics, especially African-Americans and Latinos, had higher reports of Carbon Monoxide poisoning cases. |
| Burger & Gochfeld | 2014 | 754 people within 100 days after Sandy | Interviews | | X | | | Residents were most concerned with agents of destruction, survival needs, and possessions before and during Superstorm Sandy. Medical concerns increased after the storm. Central Jersey residents had concerns over food, water, and survival after the storm. |
| Burger & Gochfeld | 2015 | 754 people within 100 days after Sandy | Interviews | | X | | | Participants were most concerned with the following: Property damage, health, inconveniences, ecological services, and nuclear power plants (in this order). |
| Burger et al. | 2013 | 754 people within 100 days after Sandy | Interviews | | X | | | Those that cannot access the internet to receive important health and safety information during the outage. Power outages as a result of Superstorm Sandy caused the web, cell phones, and social media on cell phones to be less usable so information communication strategies need to redundancies to account for power outages over widespread areas. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Call | 2010 | | Looking at the details reported by media | | X | | | Rural outages longer than urban outages. Companies concentrate on restoring main feed lines and high-priority individual lines, greater cluster means faster response times. Fallen trees isolate customers outside developed areas and prevent accurate assessments from being made. The companies fail to call enough workers or order sufficient supplies. |
| Chakalian et al. | 2019 | 42 households | Semi-structured interviews | | X | | | Households with elderly were less likely to have mental health issues, such as anxiety. Households of higher-income, white, fewer elderly children, or non-English speakers were more likely to use a generator during a power outage. Households with children were more likely to experience difficulty in accessing food and water |
| Dominianni et al. | 2018a | Customers in 7 zip codes; hospitalization and mortality data | Comparison of data during outages and normal days? | | X | | | 58% of participants claimed they were prepared for power outages. 46% of participants expressed concern about health Those who rely on a medical device were more prepared to deal with power outages. Older adults were more prepared than younger adults. |
| Dominianni et al. | 2018b | 887 respondents | A random sample telephone survey | | X | | | Do localized outages affect health more than widespread outages? |
| Esmalian et al. | 2019 | complex mechanisms underlying household's tolerance during outages | Agent-Based Model | X | X | X | | The analysis demonstrated that there is a spatial diffusion of service risks with households located in areas affected by a disaster. |
| Fife et al. | 2009 | 37 individuals exposed to CO | Review details of cases | | X | | | Children (<18) using the generator to power electronic devices puts them at greater exposure to Carbon Monoxide poisoning. More information and outreach in hurricane-prone areas are needed to reduce the number of pediatric Carbon Monoxide cases. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Gotanda et al. | 2015 | ED visits and hospitalizations, analysis is broken down by age group | Trend analysis | | X | | | Significant increase in elderly visits and hospitalizations.<br>Those that came for reasons such as "social" and "respiratory device" peaked one day after Sandy, "dialysis" peaked two days later, and "medication" peaked three days after Sandy.<br>The disproportionate effects appear because of indirect effects immediately after Sandy, such as power outages. |
| Imperato | 2016 | | Biographical account? | | X | | X | Support services for the poor, especially during the financial crisis at the time.<br>Those with health concerns/issues (specifically respiratory) or rely on medical equipment were an at-risk population during the blackout.<br>Because of the Department of Health's quick action, they were able to put together a contingency plan and mitigate the impacts of the blackout. |
| Jani et al. | 2006 | Death/injuries related to the storm | Case Study and Mixed Methods | | X | | | The presence of alcohol and drugs was apparent in deaths indirectly attributed to Hurricane Isabel (2003).<br>Being able to accurately document how many deaths were directly and indirectly attributed to a natural hazard can help in creating mitigation strategies and help inform public outreach messaging. |
| Johnson-Arbor et al. | 2014 | Patient and exposure data from CO cases reported to the Connecticut Poison Control Center | Retrospective review | | X | | | Those who use portable generators had the greatest likelihood of Carbon Monoxide poisoning within 24 hours after the 2013 snowstorm and between the second and third days of the 2011 power outage.<br>No significant difference in Carbon Monoxide poisoning cases between the two storms was found when examining age, gender, and carboxyhemoglobin concentration.<br>Outreach needs to focus on the dangers of inappropriately using generators during a power outage. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Kile et al. | 2005 | 55 state and local public health and emergency response subject matter experts | Semi-structured interviews, open-ended questionnaires | | X | | | Subject matter experts noted communication networks, backup power problems, lack of manpower and training issues, and psychosocial issues during the 2003 Northeast blackout.<br>The blackout negatively impacted municipal infrastructure, affected medical services, emergency response, and public health efforts. |
| Klein et al. | 2007 | 8 specialists on duty at the time of the blackout | Interviews | | X | | X | The average number of calls to Poison Control Centers increased during the 2003 Northeast Blackout.<br>There were significant increases in both human exposure and information calls regarding gasoline, carbon monoxide, food poisoning, and water contamination.<br>Findings from after-action reports indicate the center workers were vulnerable because of the power outage, redundant communication methods, and the increased demand for poison control services |
| Klinger et al. | 2014 | Analysis of 20 relevant articles | Systematic Lit Review | | X | | X | Access to healthcare, maintaining frontline services and challenges of community healthcare were the primary recurrent themes that emerged from their review of 20 articles.<br>The current knowledge base of the health impacts of power outages is poor. |
| Kosa et al. | 2012 | 290 older adults | Nationwide survey | | X | | | Few older adults (17% of the sample) across the United States are prepared for an extended power outage.<br>Less than 40% of the sample had followed recommended practices regarding perishable food storage.<br>The likelihood of following recommended practices was higher in women than men. |
| Lemieux | 2014 | | N/A | | X | | | Crime rates lowered when public-sector steps in with assistance.<br>Financial contributions have been inversely proportional to crime rates. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Lin et al. | 2011 | Hospital admissions during blackout vs normal days | Incidence rate ratios of incidences from blackout compared to normal days, odds ratios to compare | | X | | | Higher socioeconomic status during the blackout more likely to be hospitalized during the blackout. Mortality and respiratory cases in New York City increased significantly during the 2003 Northeast blackout. Cardiovascular and renal hospitalizations did not increase. |
| Lin et al. | 2016 | 8 counties in southern NY, including NYC | A Poisson regression model with examining power outages and relationship to ED visits | X | X | | | Those with pre-existing mental health issues, those of low socioeconomic status, minority demographics.<br>The Bronx was the most significant place of concern.<br>Emergency department visits for mental health-related issues increased after Hurricane Sandy and were positively associated with blackouts that occurred in the Bronx.<br>Power outage impacts on mental health varied in geography, especially in communities with low socioeconomic status. |
| Marx et al. | 2006 | 758 patients; 301 full interview | Case-control investigation | | X | | | Consuming food that spoiled because of a power outage, mainly meat and seafood, was associated with the increased cases in diarrheal illness during the 2003 Northeast United States blackout. |
| Matthewman & Byrd | 2014 | | N/A | | X | X | | Presents the case for what could happen in the future given the current state of infrastructure.<br>Social patterns that emerge due to power outages, including economic losses and less easily calculated costs.<br>Other issues that emerge because of power outages include finances, food safety, crime, transport issues, and issues with using diesel generators. |
| Miles & Jagielo | 2014 | 33 interviews at 18 meetings; population included public officials, Ems, business reps from 4 parishes in Louisiana | Interviews | | X | | | Those who rely on medical equipment that requires electricity were vulnerable during the power outage after Hurricane Isaac.<br>The delayed restoration was a result of winds not subsiding to safe speeds. Fewer people evacuated, which meant greater traffic and slowing down the damage assessment process and delivering assistance to affected areas.<br>People were unhappy with the restoration process, as seen by the vocal criticism of two major private |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | electric companies from the public and government officials. |
| Miles et al. | 2014 | data from interview transcripts, content in news and social media, gov't docs and databases; Reps from public agencies, hospitals, schools, and businesses; public statements, social media posts, data from SDG&E | Case Study and Mixed Methods; | | X | X | | Issues related to decision-making and communication to customers, especially health care providers, wastewater and potable water management, fuel provision, and foodservice were identified because of this study.<br>The restoration process was not communicated well, did not reflect state restoration criteria, and failed expectations of many customers. |
| Miles et al. | 2015 | 33 participants from 19 organizations | In-depth interviews | | X | X | | The results of this study indicated a few long-term impacts because of the outage and the restoration process was not unusually slow.<br>The study shows the importance of strong communication methods and raising awareness before, during, and after power outages. |
| Mitsova et al. | 2018 | Power customers in Florida | Spatial lag models | X | X | | | Rural counties experienced longer power outages and uneven restoration times.<br>There exists a positive spatial relationship between power outages and many of the social vulnerability indicators.<br>Socioeconomic variables that were statistically significant included: Minority groups, those with sensory, physical, or mental disabilities, and those who are economically vulnerable. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Mitsova et al. | 2019 | 989 households | Cross-sectional survey | | X | | | Age and race were significant predictors when relating physical damage to property, disruption of infrastructure services, and other factors (i.e. insurance coverage, disaster assistance, loss of income) after a disaster. |
| Muhlin et al. | 1981 | 2286 store records, 1970 census tracts, | Correlation/regression analyses | | X | | | Areas with greater than 10% of the population had more instances of looting during the 1977 New York City blackout.<br>Areas with less than 10% of the population being minorities had only a few occurrences of looting. |
| Muscatiello et al. | 2010 | 264 people, 155 households | Demographic analysis from information gathered from medical records. Telephone interviews with patients, if contact information was available. Chi-squared, univariate and bivariate analyses | | X | | | Portable generators being used in the ensuing power outage were too close to the home. Generators that were used inside were operated within an enclosed space.<br>Homes with gas kitchen ranges were used to generate heat.<br>Improvements to CO warning information and safety messaging must be made to reduce the risks to CO poisoning. |
| Palmieri & Greenhalgh | 2002 | 512 patients admitted during the study interval | Retrospective case=series | | X | | | Significant increases in the number of hospital admissions during the power crisis in northern California.<br>Heater-related burn admissions increased. |
| Rand et al. | 2005 | 85 patients and EMS calls | Dispatch and pre-hospital records generated during the 18-hour event compared with the median number of EMS dispatches during August 2003 and total hourly dispatches during the blackout. Presenting the complaints were also categorized and all calls during the outage were identified | | X | | | The volume of emergency calls increased on average by 250% within the first hours of the 2003 Northeast United States blackout. Heat- and respiratory-related complaints were the primary reasons for calling.<br>The average time on the scene for calls also increased during the blackout.<br>Providing supplies or creating temporary facilities for those that have medical equipment dependencies can help this population in future events. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Riddex & Dellgar | 2001 | Unknown sample size | Non-structured interviews | | X | | | 50 people had to use hyperbaric oxygen and 6 deaths were a result of CO poisoning. Hospitals were given priority in power restoration. Non-emergency services were compromised for most hospitals in eastern Canada. Prehospital services experienced an increase in emergency responses and had to provide transportation for non-ill or injured people, equipment, and supplies. Home care was interrupted and patients that received at-home care had to be transported to a hospital to receive their required treatments. |
| Román et al. | 2019 | Settlements on the island | 500m daily estimates of nighttime lights, enable detection of sub-neighborhood scale urban-lit structures, metrics related to the spatial extent, duration, and overall impact of power outages from satellite-derived products; link power recovery rates with location, demographics, and structural characteristics across municipalities. | | X | | | A disproportionate number of power failures that occurred in rural areas after Hurricane Maria. Large disparities also present within the same urban areas. Poor residents in urban areas had to deal with the longest power outages as they lived in less dense areas where restoration was slower. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Rubin & Rogers | 2019 | 47 relevant papers on public reactions after a major loss of electricity | Systematic Lit Review | | X | | | The behavioral and psychological responses of the public will influence the health, economic, and social impacts.<br>Preparing the public for power outages will help reduce the impacts.<br>Those who are considered vulnerable, especially elderly and those with psychiatric and medical conditions, need specific help to prepare.<br>Clear communication about the dangers of power outages and safe practices for using generators.<br>Loss of communication will be a great stressor for the public.<br>Panic is unlikely to occur.<br>Acts of kindness, or altruism as mentioned by the authors, will outweigh the crime.<br>The public wants to know specifically what happened and how long until the power is restored. |
| Schnall et al. | 2017 | 566 CO exposure cases; 12 PIOs | Analyzing CO cases; communications survey | | X | | | CO exposure cases mainly related to females and those of younger age.<br>Most CO cases were related to improper generator use, despite the information being communicated to the public. |
| Sugarman | 1978 | | N/A | | X | | | Looting and arson accounted for almost half of the total economic costs because of the blackout.<br>Indirect impacts must be included in determining the true costs of damages. |
| Ulak et al. | 2018 | Customers affected; identify the demographic, socioeconomic, and transportation-related variables on the magnitude of customers affected by power outages | Spatial analysis; Bayesian Spatial Autoregressive Modeling | X | X | | | Those affected by power outages are normally clustered together.<br>The number of affected people was associated with the power network and generated trips as well as various demographic factors.<br>Vulnerable locations need to be identified before an event to help reduce the impact caused by hurricane-induced power outages. |

| First Author | Year | Sample Size | Method | Modeling | Social | Technical | Other | Key Findings/Populations of Concern |
|---|---|---|---|---|---|---|---|---|
| Van Sickle et al. | 2007 | 56 households | Survey with households affected | | X | | | A generator was present for all non-fatal and fatal cases of CO poisoning.<br>Factors such as the location of the generator and generator theft influenced the decision of where to locate the generator while it was running.<br>67% of the sample was aware of the CO education messages that were communicated before the event. |
| Wohlenberg | 1982 | Number of poor persons and the number of looted stores | Regression analysis | | X | | | Areas with poor residents were more likely to have looting occur in their area.<br>Around 51% of the variation in the number of stores looted because of the 1977 New York City blackout could be accounted for by the variation in the number of poor people residing in these areas. |
| Wrenn & Conners | 1997 | 68 patients | N/A | | X | | | The main source of CO exposure was gasoline generators, propane or kerosene heaters, and charcoal grills. In Nashville, charcoal grills were the most common CO source while in Rochester, gasoline generators were the most common source.<br>Messaging must be available in multiple languages as some people in their sample did not speak English. |

B.) Survey created in Qualtrics and disseminated through Amazon's Mechanical Turk

# MTurk_Survey_2020_Codebook

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**Start of Block: Housing Block**

We are a team of researchers in the Department of Geographical Sciences and Urban Planning and the School of Sustainability at Arizona State University.  We are conducting a research study to contextualize the relationship between socio-economic status and power outage experiences in five different cities across the United States.

We are inviting your participation, which will involve an approximately 12-minute survey You have the right not to answer any question, and to stop participation at any time. Your participation in this study is voluntary. If you choose not to participate or to withdraw from the study at any time, there will be no penalty but you will not receive the payment from the Amazon MTurk service. You must be 18 or older to participate in this study.
There is no direct benefit to you and no foreseeable risks or discomforts to your participation.  Your responses will be kept confidential, only the primary research team will have access to the responses. You will be compensated $1.60 through your Mechanical Turk account for your participation if you meet the qualifications for this survey. The anonymized results of this study may be used in reports, presentations, or publications but we will not disclose your identity.

The research team will not ask your name or any other identifying information in this survey.

An anonymous numeric code will be assigned to your survey responses. Although MTurk automatically collects worker IDs for payment purposes, our research team cannot connect any survey responses to your MTurk ID.

Although Qualtrics, the survey software, does have the ability to store IP addresses, this feature will be disabled for our survey. If you choose to participate but do not meet our criteria for participation, you will be redirected to another page and will not be able to complete the survey.

If you have any questions concerning the research study, please contact the research team at David.Hondula@asu.edu. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788.

By selecting the arrow on the bottom right corner of the page, you are giving consent to completing this survey.  If you do now wish to participate, please exit out of the page.

---

Page Break

Q2 This first set of questions will ask you general questions related to power outages you have experienced.

---

Page Break

**NOTE: All choices that are listed as "Don't Know" and "Prefer not to answer" are coded as "-97" and "-98", respectively.**

Q63 Please select the major city that is the closest to your place of residence.

**Phoenix participants**

- ◯ Flagstaff (1)
- ◯ Phoenix (2)
- ◯ Tucson (9)
- ◯ Yuma (4)
- ◯ None of the above (7)

**Miami participants**

- ◯ Cape Coral (1)
- ◯ Fort Lauderdale (2)
- ◯ Hialeah (3)
- ◯ Jacksonville (4)
- ◯ Miami (5)
- ◯ Orlando (6)
- ◯ Port St. Lucie (7)
- ◯ St. Petersburg (8)
- ◯ Tallahassee (9)
- ◯ Tampa (10)
- ◯ None of the above (11)

**Detroit participants**

- ◯ Ann Arbor (1)
- ◯ Canton (12)
- ◯ Clinton (9)
- ◯ Dearborn (10)
- ◯ Detroit (8)
- ◯ Flint (2)
- ◯ Grand Rapids (3)
- ◯ Lansing (4)
- ◯ Livonia (11)
- ◯ Traverse City (5)
- ◯ None of the above (7)

---

Q4 Please enter the five-digit zip code of your primary address with no spaces.

________________________________________________________________

---

Q5 Is this address you provided the home you live in for the majority of the year (more than 6 months of the year)?

- ◯ No (1)
- ◯ Yes (2)
- ◯ Don't Know (-97)
- ◯ Prefer not to answer (-98)

---

Q6 Do you own or rent your current home?

- ◯ Own (1)
- ◯ Rent (2)
- ◯ Neither (3)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

---

Q7 Have you lived at this address for more or less than 5 years?

- ◯ Less than 5 years (1)
- ◯ Approximately 5 years (2)
- ◯ More than 5 years (3)

Q8 Have you experienced a power outage at your current address in the last five years (or since you have moved in)?

- No (1)
- Yes (2)
- Don't Know (-97)
- Prefer not to answer (-98)

Page Break

**End of Block: Housing Block**

**Start of Block: Not qualified Block**

Q105 Do you own a generator? **(Combined with Q9 in the R cleaning code)**

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

Q107 Has anyone asked to borrow your generator during a power outage?

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q117 Do you rely on a medical device that requires power in your home, such as a breathing or dialysis machine? **(Combined with Q38 in the R cleaning code)**

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

Q118 Does anyone in your household rely on a medical device that requires power, such as a breathing or dialysis machine? **(Similar to Q40?)**

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

Q109 How often do you struggle to afford essentials, such as food, housing, utilities, or medicine? **(Combined with Q42 in the R cleaning code)**

- Never (1)
- Rarely (2)
- Sometimes (3)
- Often (4)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q110 Which of these statements best describes your household in the last 12 months? **(Combined with Q43 in the R cleaning code)**

- ◯ We always have enough to eat and the kinds of food we want (1)
- ◯ We have enough to eat but not always the kinds of food we want (2)
- ◯ Sometimes we don't have enough to eat (3)
- ◯ Often we don't have enough to eat (4)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

---

Q111 Is anyone living at this primary address younger than 6 years old? **(Combined with Q44 in the R cleaning code)**

- ◯ No (1)
- ◯ Yes (2)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

---

Q112 Is anyone living at this primary address older than 64 years old? **(Combined with Q45 in the R cleaning code)**

- ○ No (1)
- ○ Yes (2)
- ○ Don't know (-97)
- ○ Prefer not to answer (-98)

Q113 In order for us to understand your unique experience, please tell us which of these categories best represents the total combined pre-tax income of EVERYONE in your household in the past year? **(Combined with Q46 in the R cleaning code)**

- ◯ Less than $5,000 (0) **This was changed from 13 to 0 in R cleaning code**
- ◯ $5,000 to $9,999 (1)
- ◯ $10,000 to $14,999 (2)
- ◯ $15,000 to $19,999 (3)
- ◯ $20,000 to $39,999 (4)
- ◯ $40,000 to $59,999 (5)
- ◯ $60,000 to $79,999 (6)
- ◯ $80,000 to $99,999 (7)
- ◯ $100,000 to $119,999 (8)
- ◯ $120,000 to $199,999 (9)
- ◯ $200,000 and over (10)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

Q114 Which of these categories best represents YOUR OWN personal pre-tax income (e.g., wages, tips, dividends, etc., that you alone have earned) in the past year? **(Combined with Q47 in the R cleaning code)**

- Less than $5,000 (0) **Changed from 13 to 0 in R cleaning code**
- $5,000 to $9,999 (1)
- $10,000 to $14,999 (2)
- $15,000 to $19,999 (3)
- $20,000 to $39,999 (4)
- $40,000 to $59,999 (5)
- $60,000 to $79,999 (6)
- $80,000 to $99,999 (7)
- $100,000 to $119,999 (8)
- $120,000 to $199,999 (9)
- $200,000 and over (10)
- Don't know (-97)
- Prefer not to answer (-98)

Q115 With which of these common racialized groups do you identify?

- ▢ Native American or American Indian (1)
- ▢ Asian or Asian American (2)
- ▢ Black or African American (3)
- ▢ Hispanic, Latino, Mexican, Mexican-American or Spanish (4)
- ▢ Middle Eastern (5)
- ▢ Native Hawaiian or Other Pacific Islander (6)
- ▢ White or caucasian (7)
- ▢ Other (8)
- ▢ Don't know (-97)
- ▢ Prefer not to answer (-98)

**End of Block: Not qualified Block**

---

**Start of Block: Generator Questions**

Q9 Do you currently own a generator? **(Combined with Q105 in the R cleaning code to be Q901_Generator)**

- ◯ No (1)
- ◯ Yes (2)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

*Skip To: Q13 If Do you currently own a generator? != Yes*

---

Q10 How long have you owned your generator?

- ◯ Less than 1 year (1)
- ◯ 1-5 years (2)
- ◯ More than 5 years (3)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

---

Q11 Did you purchase this generator in anticipation of future power outages (as opposed to another reason, such as work or powering a recreational vehicle (RV))?

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q30 During the LONGEST power outage you have experienced in the past five years, did you use your generator?

- No (1)
- Yes (2)
- Don't Know (-97)
- Prefer not to answer (-98)

---

*Display This Question:*

*If During the LONGEST power outage you have experienced in the past five years, did you use your gen... != Yes*

Q31 Why did you NOT use your generator during your LONGEST outage?

- ◯ It was not working or was broken (1)
- ◯ It had no fuel (2)
- ◯ I was not confident in its operation or unsure of how to operate it (3)
- ◯ It was too expensive to use (4)
- ◯ It was too loud or noisy to use (5)
- ◯ I was concerned about, or bothered by, exhaust fumes (6)
- ◯ Another reason (7) ________________________________________________

---

*Display This Question:*

*If During the LONGEST power outage you have experienced in the past five years, did you use your gen... = Yes*

Q32 During your LONGEST outage, please give your best estimate what distance your generator was from your home while it was running.

- Inside my home (1)
- Next to my home - 10 feet away (0'-10') (2)
- 11-24 feet away (11'-24') (3)
- 25 feet away or more (25'+) (4)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q12 Approximately how often does your generator receive maintenance or service (e.g., change the fuel, oil, air filter, check battery capacity, etc.)?

- 6 months or less (1)
- Once a year (2)
- Once every two years (3)
- Less frequently than once every two years (4)
- Never (5)
- Don’t know (-97)
- Prefer not to answer (-98)

---

Q13 Do you have a carbon monoxide alarm or detector in your home?

- ◯ No (1)
- ◯ Yes (2)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

*Skip To: End of Block If Do you have a carbon monoxide alarm or detector in your home? != Yes*

Q14 Approximately, how often do you test your carbon monoxide detector or alarm?

- ◯ Once a week (1)
- ◯ Once a month (2)
- ◯ Once a year (3)
- ◯ Never (4)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

Page Break

**End of Block: Generator Questions**

**Start of Block: General Power Outage Questions**

Q15 Approximately how many outages have you experienced at your primary address in the last five years?

- ○ 1-5 (1)
- ○ 5-10 (2)
- ○ 10-15 (3)
- ○ 15-30 (4)
- ○ Don't know (-97)
- ○ Prefer not to answer (-98)

Q16 Have you had to throw away food that became spoiled or unusable as a result of a power outage?

- ○ No (1)
- ○ Yes (2)
- ○ Don't know (-97)
- ○ Prefer not to answer (-98)

---

Q17 Have you received any assistance from a public or private organization (e.g. FEMA, a local store, your insurance, or your utility company) because of an extended power outage?  Please check all that apply.

- ▢ I received no assistance  (1)
- ▢ I received free ice  (2)
- ▢ I received bottled or otherwise publicly distributed water for drinking  (3)
- ▢ I received battery-operated fans, portable air conditioning units, or other cooling devices  (4)
- ▢ I received housing and/or shelter (e.g. housing/hotel vouchers, or using a public shelter)  (5)
- ▢ I received replacement food  (6)
- ▢ I received candles, flashlights, battery-powered lamps, or other light sources  (7)
- ▢ I received cash, insurance reimbursement, or other monetary compensation (e.g. gift card)  (8)
- ▢ I received FEMA Disaster Assistance funds  (9)
- ▢ I have not yet received cash, monetary compensation, or disaster assistance funds but expect to  (10)
- ▢ Other  (11)
- ▢ Don't know  (-97)
- ▢ Prefer not to answer  (-98)

*Display This Question:*

*If Have you received any assistance from a public or private organization (e.g. FEMA, a local store,... != I received no assistance*

*Or Have you received any assistance from a public or private organization (e.g. FEMA, a local store,... != Don't know*

*Or Have you received any assistance from a public or private organization (e.g. FEMA, a local store,... != Prefer not to answer*

Q18 From which organization(s) did you receive assistance? Please check all that apply.

- ▢ An electrical utility company (1)
- ▢ A church or other local charitable organization (2)
- ▢ A national or international charitable organization, e.g. The Red Cross, Salvation Army, etc. (3)
- ▢ My local or state government (4)
- ▢ Federal government (FEMA, DHS, etc.) (5)
- ▢ A local store or for-profit organization (e.g. Home Depot, Walmart, etc.) (6)
- ▢ Other (7) ________________________________________________
- ▢ Don't know (-97)
- ▢ Prefer not to answer (-98)

*Display This Question:*

*If From which organization(s) did you receive assistance? Please check all that apply. != Don’t know*

*Or From which organization(s) did you receive assistance? Please check all that apply. != Prefer not to answer*

*Or Have you received any assistance from a public or private organization (e.g. FEMA, a local store,... != I received no assistance*

Q19 Please provide the names of the organizations that provided assistance.

________________________________________________________________

Page Break

**End of Block: General Power Outage Questions**

**Start of Block: Most Recent Outage**

Q20 What was the approximate length of your MOST RECENT outage?

○ Less than 1 hour (1)

○ 1-6 hours (2)

○ 6-12 hours (3)

○ 12--24 hours (4)

○ 1-3 days (5)

○ 3-7 days (6)

○ Don't know (-97)

○ Prefer not to answer (-98)

---

Q21 What was the approximate MONTH AND YEAR of your MOST RECENT outage?

________________________________________________________________

---

Page Break

**End of Block: Most Recent Outage**

**Start of Block: LONGEST Power Outage**

Q22 The next section of the survey is going to ask questions about your LONGEST power outage within the last five (5) years. Questions will also remind you that we are asking about the longest power outage.

Page Break

Q23 Within the last 5 years, approximately what was the LONGEST period of time your primary address was without power?

- Less than 1 hour (1)
- 1-6 hours (2)
- 6-12 hours (3)
- 12-24 hours (4)
- 1-3 days (5)
- 3-7 days (6)
- More than 7 days (7)
- Don't know (-97)
- Prefer not to answer (-98)

Q24 What was the approximate MONTH AND YEAR of your LONGEST outage?

________________________________________________________________

Q26 Did you leave your home to go somewhere else during your LONGEST power outage?

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

*Display This Question:*

*If Did you leave your home to go somewhere else during your LONGEST power outage? = Yes*

Q27 Where did you go?

- A friend’s, family member’s, or neighbor’s (1)
- A hotel, motel, or other lodging that you had to pay for (2)
- A movie theater, shopping mall, or other commercial space (3)
- A public park, library, or other public place (4)
- Somewhere else (5)
- Don’t know (-97)
- Prefer not to answer (-98)

---

Q25 How long were you living in your home without power during your LONGEST outage? Please exclude days you spent away from home (for example, stayed with friends or family, went to a public place with power, etc.)

- ○ Less than 1 hour (1)
- ○ 1-6 hours (2)
- ○ 6-12 hours (3)
- ○ 12--24 hours (4)
- ○ 1-3 days (5)
- ○ 3-7 days (6)
- ○ Don't know (-97)
- ○ Prefer not to answer (-98)

---

Q28 Were you aware that you may lose power prior to your LONGEST outage?

- ○ Yes, the same day that I lost power (1)
- ○ Yes, the day before I lost power (2)
- ○ Yes, one to three days before I lost power (3)
- ○ Yes, four or more days before I lost power (4)
- ○ No, I was not notified. (5)

---

*Display This Question:*

*If Were you aware that you may lose power prior to your LONGEST outage? != No, I was not notified.*

Q29 How were you notified?

- ◯ Through word-of-mouth including through a friend, family member, or neighbor. (1)
- ◯ Through traditional news including radio, television, newspaper, etc. (2)
- ◯ Through online social media including Twitter, Facebook, etc. (3)
- ◯ From weather forecasters or meteorologists (4)
- ◯ From local emergency officials including the fire department, police, etc. (5)
- ◯ From other government officials (6)
- ◯ Somewhere else (7)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

Q33 Did you use anyone else's generator during your LONGEST power outage? (This includes running an extension cable to your house from a neighbor's generator, or going to another house to use their generator).

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q34 Was access to food or water more difficult for you during your LONGEST power outage?

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q35 During your LONGEST power outage, were you able to use water from your primary address' home taps, sink, showers, bathtubs, or hoses?

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

Q36 What other water did you use for drinking?

- Bottled water purchased at a store after the power went out (1)
- Bottled water already in home before the power went out (2)
- Personally stored water (not purchased at a store) already in home (3)
- Water provided free from a neighbor, volunteer, or aid or emergency organization (4)
- Water from a natural source including a well, stream, reservoir, etc. (5)
- Something else (6)
- Don't know (-97)

Q37 How much of a financial burden was losing electrical power during your LONGEST power outage? Include the cost of supplies such as fuel, generator, candles, batteries, emergency food or water, etc.

- Not at all burdensome (1)
- A little burdensome (2)
- Somewhat burdensome (3)
- Very burdensome (4)
- Extremely burdensome (5)
- Don't know (-97)
- Prefer not to answer (-98)

Q38 Do you rely on a medical device that requires power in your home, such as a breathing or a dialysis machine? **(Combined with Q117 in the R cleaning code and )**

- ◯ No (1)
- ◯ Yes (2)
- ◯ Don't know (-97)
- ◯ Prefer not to answer (-98)

*Display This Question:*

*If Do you rely on a medical device that requires power in your home, such as a breathing or a dialys... = Yes*

Q39 How did you manage your medical condition during your LONGEST power outage? Select all that apply.

- ☐ Waited for the power to come back on (1)
- ☐ Went somewhere else with power (2)
- ☐ Called for help from a friend or relative (3)
- ☐ Called for help from an emergency service such as 911 (4)
- ☐ Used a generator for backup power (5)
- ☐ Used a backup battery for the device (6)
- ☐ Another way (7)
- ☐ Don’t know (-97)
- ☐ Prefer not to answer (-98)

Q40 Did anyone in your household face problems with access to needed medical care because of your LONGEST power outage?  This includes problems accessing prescription medications, medical devices, and/or care for injuries, falls, burns, illnesses, etc.

- ○ No  (1)
- ○ Yes  (2)
- ○ Don't know  (-97)
- ○ Prefer not to answer  (-98)

---

Page Break

**End of Block: LONGEST Power Outage**

---

**Start of Block: General Demographic Questions**

Q41 The last set of questions will ask about household information. Please provide all responses to the best of your ability.

---

Page Break

Q42 How often do you struggle to afford essentials, such as food, housing, utilities, or medicine? **(Combined with Q109 in the R cleaning code)**

- ○ Never (1)
- ○ Rarely (2)
- ○ Sometimes (3)
- ○ Often (4)
- ○ Don't know (-97)
- ○ Prefer not to answer (-98)

---

Q43 Which of these statements best describes your household in the last 12 months? **(Combined with Q110 in the R cleaning code)**

- ○ We always have enough to eat and the kinds of food we want (1)
- ○ We have enough to eat but not always the kinds of food we want (2)
- ○ Sometimes we don’t have enough to eat (3)
- ○ Often we don’t have enough to eat (4)
- ○ Don’t know (-97)
- ○ Prefer not to answer (-98)

---

Q44 Is anyone living at this primary address younger than 6 years old? **(Combined with Q111 in the R cleaning code)**

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

---

Q45 Is anyone living at this primary address older than 64 years old? **(Combined with Q112 in the R cleaning code)**

- No (1)
- Yes (2)
- Don't know (-97)
- Prefer not to answer (-98)

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Q46 In order for us to understand your unique experience, please tell us which of these categories best represents the total combined pre-tax income of EVERYONE in your household in the past year? **(Combined with Q113 in the R cleaning code)**

- ○ Less than $5,000  (0) **Changed from 13 to 0 in R cleaning code**
- ○ $5,000 to $9,999  (1)
- ○ $10,000 to $14,999  (2)
- ○ $15,000 to $19,999  (3)
- ○ $20,000 to $39,999  (4)
- ○ $40,000 to $59,999  (5)
- ○ $60,000 to $79,999  (6)
- ○ $80,000 to $99,999  (7)
- ○ $100,000 to $119,999  (8)
- ○ $120,000 to $199,999  (9)
- ○ $200,000 and over  (10)
- ○ Don't know  (-97)
- ○ Prefer not to answer  (-98)

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Q47 Which of these categories best represents YOUR OWN personal pre-tax income (e.g., wages, tips, dividends, etc., that you alone have earned) in the past year? **(Combined with Q114 in the R cleaning code)**

- Less than $5,000 (0) **Changed from 13 to 0 in R cleaning code**
- $5,000 to $9,999 (1)
- $10,000 to $14,999 (2)
- $15,000 to $19,999 (3)
- $20,000 to $39,999 (4)
- $40,000 to $59,999 (5)
- $60,000 to $79,999 (6)
- $80,000 to $99,999 (7)
- $100,000 to $119,999 (8)
- $120,000 to $199,999 (9)
- $200,000 and over (10)
- Don't know (-97)
- Prefer not to answer (-98)

Q48 With which of these common racialized groups do you identify? **(Combined with Q115 in the R cleaning code)**

- ☐ Native American or American Indian (1)
- ☐ Asian or Asian American (2)
- ☐ Black or African American (3)
- ☐ Hispanic, Latino, Mexican, Mexican-American or Spanish (4)
- ☐ Middle Eastern (5)
- ☐ Native Hawaiian or Other Pacific Islander (6)
- ☐ White or caucasian (7)
- ☐ Other (8)
- ☐ Don't know (-97)
- ☐ Prefer not to answer (-98)

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Q49 Is there anything else that you would like to tell us?

________________________________________________________________

________________________________________________________________

________________________________________________________________

________________________________________________________________

Page Break

**End of Block: General Demographic Questions**

**Start of Block: Block 7**

Q104 Thank you so much for completing our survey! Please enter this four-digit verification number into MTurk to be eligible to receive payment: **${rand://int/1000:9999}**

**End of Block: Block 7**

**CODE UPDATES as of June 7, 2020**

Q901_Generator- Combined Q9 and Q115

Q902_DeviceSelf- Combined Q38 and Q117

Q903_StruggleEssentials- Combined Q42 and Q109

Q904_HouseholdStatement- Combined Q43 and Q110

Q905_Under6- Combined Q44 and Q111

Q906_Over64- Combined Q45 and Q112

Q907_IncomeHouse- Combined Q46 and Q113

Q908_IncomeSelf- Combined Q47 and Q114

Q909_Demographics- Combined Q48 and Q115

- Each demographic has a column to set up a binary system (Yes=2/No=1)
- Q909_Indian, Q909_Asian, Q909_Black, Q909_Hispanic, Q909_MidEast, Q909_NatPacIsl, Q909_White, Q909_OtherDem, Q909_PNTADem

**NEW QUESTIONS LISTED HERE WERE RECODED TO MAKE RESPONSES BINARY.**

**ALL RESPONSES THAT WERE -97 OR -98 WERE LISTED AS "NA" AND ARE NOT INCLUDED WITHIN THE ANALYSIS**

Q1009_WhiteRecode -> 1- Not white, 2- White (From Q909)

Q1007_LowIncome -> 1- High income, 2- Low income (From Q907)

Q1001_GenOwn -> 1- Do not own generator, 2- Own a generator (From Q901)

Q1005_Under6Recode -> 1- No one in the house is under 6 years old, 2- Someone in the house is under 6 years old (From Q905)

Q1006_Over64Recode -> 1- No one in the house is over 64 years old, 2- Someone in the house over 64 years old (From Q906)

Q1011_GenPurchaseRecode -> 1- Did not purchase a generator in advance of future power outages, 2- Purchased generator in advance of future power outages (From Q11)

Q1010_GenOwnTimeRecode -> 1- Owned generator for less than 1 year, 2- Owned generator for more than 1 year (From Q10)

Q1015_ManyOutages -> 1- Less than 10 outages in the last 5 years, 2- More than 10 outages in the 5 years (From Q15)

Q1003_NotEnoughFoodRecode -> 1- Rarely struggles to afford essentials, 2- Often struggles to afford essentials (From Q903)

Q928_NotAware -> 1- Aware longest outage would happen, 2- Not aware longest outage would occur (From Q28)

Q920_RecentOutage -> 1- More than 1 day, 2- Less than 1 day (From Q20)
Q923_LongestOutage -> 1- More than 1 day, 2- Less than 1 day (From Q23)
Q925_AtHome -> 1- More than 1 day, 2- Less than 1 day (From Q25)