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Analyzing changes to U.S. municipal heat response plans during the COVID-19 pandemic

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\textbf{ABSTRACT}

Extreme heat events are the deadliest weather-related event in the United States. Cities throughout the United States have worked to develop heat adaptation strategies to limit the impact of extreme heat on vulnerable populations. However, the COVID-19 pandemic presented unprecedented challenges to local governments. This paper provides a preliminary review of strategies and interventions used to manage compound COVID-19-extreme heat events in the 25 most populous cities of the United States. Heat adaptation strategies employed prior to the COVID-19 pandemic were not adequate to meet during the co-occurring compound hazard of COVID-19-EHE. Long-term climate-adaptation strategies will require leveraging physical, financial, and community resources across multiple city departments to meet the needs of compound hazards, such as COVID-19 and extreme heat.

\section{Introduction}

Extreme heat events (EHEs) are currently the deadliest weather-related events in the United States (Uejio et al., 2011), and they are expected to grow in intensity, frequency, and duration due to a warming climate (Meehl and Tebaldi, 2004). In the period spanning 2004 to 2018, an average of 701 people died annually in the U.S. due to heat-related illness (Vaidyanathan et al., 2004). The health impacts of EHEs are being amplified by factors such as the intensification of the urban heat island effect and increased vulnerability due to aging populations (Heaviside et al., 2017).

In response to the growing threat of EHEs, many communities have developed heat response plans that identify risk factors, high-risk populations, and methods to protect their most vulnerable residents that might not otherwise have protection from heat exposure (Luber and McGeehin, 2008). In the United States, heat response plans are coordinated plans to organize activities to prevent heat-related morbidity and mortality, often in response to National Weather Service advisories (e.g., heat watches, heat warnings, or heat advisories) (Abbinett et al., 2020). U.S. heat response plans tend to be created and implemented by local governments and therefore vary regionally with each municipality creating heat response plans to meet local needs and available resources.

Local government heat responses typically include measures to (a) define factors that magnify the health-based consequences of EHE exposure, (b) identify and inform high-risk populations of their options to mitigate EHE threats at a household level, and (c) provide facilities and resources to underserved and at-risk communities (e.g., cooling centers) (Vaidyanathan et al., 2004). These plans can range from cursory written measures to comprehensive heat response plans that involve many city departments and partnerships with nongovernmental organizations in efforts to implement strategies to target at-risk individuals and provide resources to cooling centers (Bernard and McGeehin, 2004). They typically include measures to reduce heat-related health impacts by implementing public outreach and heat adaptation strategies such as working with local media to broadcast emergency warnings, opening cooling centers, distributing instructions on how to identify heat illness, extending open hours at beaches and public pools, and implementing outreach programs to check on the heat vulnerable (Bernard and McGeehin, 2004; Klinenberg, 2002; U.S. EPA, 2016). Local contexts, such as political will, infrastructural and financial resources, demographics, and experiences with past heat waves, impact the types of interventions considered and the ability to implement those interventions (White-Newsome et al., 2014).

Even when heat response plans are comprehensive, individual perceptions of extreme heat can prevent heat interventions from being effective. While multiple survey studies conducted throughout United States

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States cities have found that a majority of respondents are aware of heat events, many respondents in these studies claim that they chose not to modify their behaviors as a result of financial insecurity (i.e., residents could not afford to use air conditioners due to electricity costs) or because respondents did not consider heat to pose a significant danger to their health (Sheridan, 2007; Hayden et al., 2017; Kalkstein and Sheridan, 2007; Hayden et al., 2011; Semenza et al., 2008)

One major risk factor for heat illness and heat-related mortality is access to air conditioning (Kilbourne et al., 1982). Cities have historically opened public cooling centers in an attempt to reduce heat-related morbidity and mortality by providing cool public spaces in air-conditioned buildings to offer vulnerable populations safety during periods of extreme heat (Widerynski et al., 2017). While cooling centers have been widely used throughout U.S. cities, their efficacy to reduce heat-related mortality is undetermined (Hansen et al., 2011). Cooling centers are only effective if the heat-vulnerable can access them. Multiple surveys of heat-vulnerable households have found that respondents do not know cooling resources exist or felt that resources were unavailable to them (e.g., believing they were only for the elderly) (Hayden et al., 2017; Semenza et al., 2008; Hansen et al., 2011; Lane et al., 2021)

Residents and community leaders in multiple survey studies also reported that transportation access and lack of walkability to cooling centers are key barriers to cooling resource utilization in many heat-vulnerable populations, such as elderly persons with limited mobility (Sheridan, 2007).

While the effectiveness of official cooling centers is not well understood, there is significant evidence to suggest that providing publicly accessible cooling resources is effective in reducing the heat impact of EHEs. Physical improvements that support safe, walkable streets can accessible cooling resources is effective in reducing the health impact of EHEs (Sheridan, 2007; Hayden et al., 2011; Semenza et al., 2008; Hansen et al., 2011; Lane et al., 2021)

The COVID-19 pandemic made opening public spaces for congregation more difficult in the summer of 2020 due to the nature of disease transmission. As a result, creating robust plans to protect the public against the public health threats of EHEs was much more difficult because of key epidemic safety protocols, namely social distancing, capacity restrictions, and/or the closure of many public spaces altogether. City managers had to weigh the reopening of many cool-spaces like shopping malls, libraries and other de-facto cooling centers were within walking distance to much higher numbers of households (80% in Los Angeles, 39% in Maricopa) (Fraser et al., 2017).

The COVID-19 pandemic made opening public spaces for congregation more difficult in the summer of 2020 due to the nature of disease transmission. As a result, creating robust plans to protect the public against the public health threats of EHEs was much more difficult because of key epidemic safety protocols, namely social distancing, capacity restrictions, and/or the closure of many public spaces altogether. City managers had toweigh the re-opening of many cool-spaces like pools, beaches, and businesses with COVID-19 concerns (Martinez et al., 2020), as emergency response agencies, at both federal and local levels, were tasked with coordinating responses to both COVID-19 and climate disasters (Phillips et al., 2020).

Furthermore, the economic impact of COVID-19 related policies (e.g., job loss, furloughs, increased costs for utilities, reduced access to public transportation etc.) tended to exacerbate the long-standing socioeconomic and racial disparities that increase risks of poor health outcomes in specific populations. In addition to raising risks to severe disease, these economic hardships reduced the ability of vulnerable populations to afford interventions that provide protection from extreme heat (e.g., air conditioning, paying utility bills, transportation to cooling centers, etc.).

More broadly speaking, protecting the public from the threats of acute and recurring weather-related events such as heat waves, hurricanes, tornados, and wildfires has become more expensive and more challenging over time (Hoeppke, 2016; Kron et al., 2019) While these seasonal phenomena have already stretched limited governmental resources at the federal, state and local levels in recent years, responding to these natural disasters while simultaneously managing a contagious disease during the COVID-19 pandemic added a great deal of complexity to developing adequate governmental responses. Given that most experts expect that contagious epidemics are likely to reoccur in the future (Bedford et al., 2019), analyzing the successes and failures of governments to respond to concurrent disasters during the summer of 2020 is prudent.

In this manuscript we investigate how compound extreme heat-pandemic hazards were managed in the 25 largest cities in the United States (by population) during the period spanning from April through September 2020. First, we compiled a database detailing the municipal response of these cities to compound EHE-pandemic hazards in Summer 2020, then we discuss these municipal responses across a range of heat response classifications. Finally, we comment on lessons learned and potential interventions to improve future responses to compound events.

2. Methodology

Our study analyzed the heat response of the 25 largest U.S. cities by population size through the period spanning from April 1st to September 30th, 2020 (US Census Bureau, 2019) After an initial search of response policies, we identified four key categories of COVID-19-EHE adaptation strategies, which include heat warnings, cooling centers, alternative cooling resources, and utility assistance and shutoffs. For each category of cooling strategy, we tracked whether a strategy was initiated, whether there were specific modifications to those strategies for COVID-19 related concerns, and whether a given strategy was reduced in magnitude in comparison to pre-pandemic strategies.

For each city, we performed keyword searches on Google News for each month included in our study period. We also searched each city’s website, including public health and emergency departments, as well as local news outlets for heat related notifications. For heat warning systems, we looked at both news posts as well as the local National Weather Service’s Twitter account (National Weather Service, 2021). We did not track cooling centers or alternative cooling facilities provided by non-governmental organizations unless they were working directly in conjunction with city or county governments to open centers.

This methodology assumes that information regarding heat response plans was released and made publicly available via online documents, including government released sites and news-based sites. Hence, one key limitation of our search was that plans developed and conceived offline would not appear in our results. Despite this potential limitation, the findings of our search compiles information that could have been accessed by heat vulnerable populations in efforts to find relief, even if they do not represent a fully comprehensive list of all heat response measures taken during COVID-19. As a result, the findings of this search are likely to present more results for cities that experienced more extreme events during our study period. Cities that had few or no EHEs during this period may have never publicized heat response plans, even if they were developed.

3. Results: municipal responses to COVID-19-EHE events

Here we discuss the results of our review of heat response plans, which are summarized in Table 1.

Heat-health warning systems and heat-health action plans are key components of reduce the morbidity and mortality of extreme heat on the populations by notifying the public of inclement extreme heat and initiating emergency public health interventions (Ebi et al., 2004; Casanueva et al., 2019). Table 1 demonstrates that of the cities in our study group, only Seattle did not have a National Weather Service heat notice (i.e., met local qualifications to issue a heat advisory or excessive heat warning).

Heat plans varied throughout the United States. Most cities within our study did not post a formal comprehensive heat plan to the public. Only three cities, New York, Chicago, and Houston posted formal heat plans to the public that were adapted to COVID-19 restrictions. Two others, Los Angeles and Philadelphia, reported COVID-19 heat plans were in progress at the end of the summer of 2020. While not all cities
Table 1
The review of the COVID-19-EH response strategies for 25 largest cities the United States from April 1st, 2020, to October 30th, 2020 are highlighted here. Information in this table has been derived from publicly available press releases, news articles, and social media posts by cities. Four key excessive heat reduction strategies – heat warnings, cooling centers, alternative cooling resources, and cost reduction strategies – are summarized in this table.

| CITY         | Date of Adherence | COVID-19-EH Response Strategy | Cost Reduction Strategies | COVID-19 Health | MHWI on Sheds |
|--------------|-------------------|--------------------------------|---------------------------|-----------------|--------------|
| NEW YORK     | April 15, 2020    | Adapted to COVID-19            | Yes                        | No              | Yes          |
| LOS ANGELES  | April 19, 2020    | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| CHICAGO      | May 17, 2020      | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| HOUSTON      | June 15, 2020     | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| PHOENIX      | May 19, 2020      | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| PHILADELPHIA | April 12, 2020    | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| SAN ANTONIO  | June 14, 2020     | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| SAN DIEGO    | April 20, 2020    | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| DALLAS       | July 14, 2020     | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| SAN JOSE     | July 21, 2020     | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| AUSTIN       | July 21, 2020     | Adapted to COVID-19            | Yes                        | Limited          | Yes          |
| JACKSONVILLE | September 22, 2020| Adapted to COVID-19            | Yes                        | Limited          | Yes          |

(continued on next page)
| Location       | Date       | Action  | Yes? | Community Center  | Closing Date | Notes |
|---------------|------------|---------|------|-------------------|--------------|-------|
| Fort Worth    | July 20th  | Opened  | Yes  | 100 Community Centers | September 15th |       |
| Columbus      | July 1st   | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Charlotte     | August 1st | Closed  | Yes  | 100 Community Centers | September 15th |       |
| San Francisco | August 10th| Closed  | Yes  | 100 Community Centers | September 15th |       |
| Indianapolis  | August 12th| Closed  | Yes  | 100 Community Centers | September 15th |       |
| Seattle       | July 21st  | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Denver        | July 22nd  | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Washington    | July 7th   | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Boston        | July 13th  | Opened  | Yes  | 100 Community Centers | September 15th |       |
| El Paso       | August 15th| Closed  | Yes  | 100 Community Centers | September 15th |       |
| Nashville     | July 13th  | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Detroit       | July 17th  | Closed  | Yes  | 100 Community Centers | September 15th |       |
| Oklahoma City | July 12th  | Closed  | Yes  | 100 Community Centers | September 15th |       |

*This list is not meant to be comprehensive. Rather, it aims to identify the diverse strategies and portfolios of policies that different states employed to adapt to COVID-19.*

Anon, 2020a, Schuerman, 2019, New York City Agencies, 2020, City of New York, 2020, Office of The Mayor of New York City, 2021, New York Senate, 2020, Fry, 2020, Daily News, 2020, NBC Los Angeles, 2021a, Los Angeles Times, 2021a, Lloyd and De Leon, 2021, Los Angeles Times, 2021b, Davenport, 2020, ABC7 Los Angeles, 2020, NBC Los Angeles, 2021b, Los Angeles County Cooling Centers, 2020, Cooling Center FAQs Cooling Centers and COVID-19, 2021, Reynolds, 2020, Chen et al., 2021t, Office of Los Angeles Mayor Eric Garcetti, 2019, Heat, holiday to close L.A, 2020, CBS Chicago, 2020, Anon, 2021b, Chicago Tribune, 1995, ComEd – An Exelon Company, 2020, Anon, 2021m, City of Chicago, 2020, Anon, 2021e, Anon, 2021n, Anon, 2020b, khou.com, 2021, Houston Public Media, 2021, McCord, 2021, Anon, 2021r, CBS Dallas/Fort Worth, 2021a, Anon, 2021l, Delony and Bennett, 2020, NWS Phoenix, 2020, Anon, 2021p, Anon, 2021v, 12news.com, 2021, Anon, 2021d, Anon, 2021d, Wood (2020), NBC10 Philadelphia, 2021, City of Phoenix, 2020, Wood, 2020, Horn, 2019, Jaramillo and Meyer, 2021, PhillyVoice, 2020, 2021, City of Philadelphia, 2021, LIHEAP Recovery Crisis Program, 2021, Metro Health Issues Heat Advisory Level III and Ozone Action Day, 2021, Metro Health Issues Heat Advisory, 2021, Anon, 2021k, Anon, 2021a, NWS Austin/San Antonio on Twitter, 2020a, NWS Austin/San Antonio on Twitter, 2020b, City of City of City of San Antonio Opening Cooling Centers, 2020, Ibanez, 2021, Carden, 2019, Anon, 2021a, Catholic Charities, 2021, Iranpour, 2021, Times of San Diego, 2021, KPBS, 2021, NBC 7 San Diego, 2021, FOX 5 San Diego, 2021, County of San Diego, 2020a, cbs8.com, 2021, Anon, 2021g, Cool Zones, 2021, County of San Diego, 2020b, Cool Zone Sites 2019, 2019, San Diego Reader, 2021, Los Angeles Times, 2021c, Francisco, 2020, Anon, 2021o, Anon, 2021aa, CBS Dallas/Fort Worth, 2021b, Anon, 2021aa, wfaa.com, 2021, NBC 5 Dallas-Fort Worth, 2021, Jimenez, 2020, Anon, 2021f, Anon, 2021g, Anon, 2021e, Favro, 2020, NBC Bay Area, 2021, San Jose Spotlight, 2020, PG&E, 2021, Williams et al., 2021, Anon, 2021w, Villalpando, 2020, Plahetki, 2020, Anon, 2021h, Anon, 2021j, Minor, 2021, Anon, 2021a, Austin.com, 2020, Anon, 2021p, Fort Worth Star-Telegram, 2021, Harding and Piggott, 2020, WSYX, 2021a, WSYX, 2021b, Fenter, 2020, Anon, 2021x, City of Dallas – Office of Emergency Management, 2020, Anon, 2021c, NBC 5 Dallas-Fort Worth, 2021, Anon, 2021f, cablewoodi.com, 2021, Anon, 2021p, myfox8.com, 2021, Charlotte Observer, 2021, Charlotte Mecklenburg Emergency Management Office, 2020, Anon, 2020a, Nicco and Patel, 2021, Buchmann and Hwang, 2020, NBC Bay Area, 2020, Nicco, 2021, San Francisco Department of Public Health, 2020, 2020, San Francisco Department of Emergency Management, 2020, CBS SF Bay Area, 2021, CBS SF Bay Area, 2020, Mack, 2020, CBS SF Bay Area, 2020, Sims, 2020, Sims, 2021, Gibson, 2020, King 5, 2020, The Seattle Times, 2021, Parkways, 2021, Ratepayer Assistance and Preservation of Essential Services, 2021, Kirk, 2020, Bote, 2021, Thomas, 2020, Morrison, 2020, Government of the District of Columbia, 2020, Schultz (2020), wsusa9.com, 2021, Department of Energy & Environment, 2021, District of Columbia Public Service Commission, 2020, District of Columbia Public Service Commission, 2002, Williams, 2020, Epstein, 2020, VCWV, 2020, Public Health Commission, 2020, Boston 25 News, 2020, Sobey, 2019, Slane, 2020, Gilvarg (2020), KTSM 9 News, 2021, Gilvarg, 2020, Miner, 2020, Parker, 2020a, Parker, 2020b, Borunda, 2020, El Paso City-County Office of Emergency Management, 2020, KFOX 14, 2020, Bock, 2020, El Paso Herald Post, 2020, WNSNashville, 2020, Nashville, 2020, Jorge, 2020, Tennessee Public Utility Commission, 2020), Anon, 2021p, City of Detroit, 2020, CBS Detroit, 2020, Hall, 2020a, Hall (2020b), Rahman, 2020, Sweetman, 2020, Oklahoma Gas & Electric, 2020.
developed publicly outlined heat plans, a majority of cities initiated heat-related adaptation strategies.

Though best practices for joint COVID-19-EHE preparedness remain elusive, some jurisdictions adapted existing strategies or resourced new initiatives to address EHE throughout the summer of 2020. New York City (NYC) took an aggressive stance to mitigate heat risk during COVID-19 with a prevention focused policy. The city created a $55 million initiative to provide 74,000 air conditioning units to vulnerable populations and identified existing facilities, cooling elements, and other resources that could be used as key cooling centers in high-risk communities, planned appropriate social distancing and providing personal protective equipment (PPE) (Office of The Mayor of New York City, 2021). In addition to this air conditioning program, the New York State Public Service commission approved an additional $70.56 million emergency cooling bill relief program for four months that made electric customers eligible to receive up to $40 a month in electricity bill relief (Denn, 2020).

Not all cities were able to take such an aggressive heat response measures as NYC during the summer of 2020, typically due to limited financial resources. For example, in Philadelphia, pandemic-related budget cuts led to a 20% reduction in its parks and recreation budgets forcing 74 public pools and 152 recreational centers to close for the summer 2020 season. To alleviate the lost cooling facilities, the city department raised $600,000 in six weeks for its Playstreets program, which acted as an extension of federal free lunch programs to provide 100 streets throughout Philadelphia with free tents, patio umbrellas, misting fans, super soakers, water jugs, water balloons, and neck cooling rags (Jaramillo, 2020).

3.1. Cooling centers

Cooling center response strategies were largely characterized in this study according to reductions in the number of locations available, capacity of centers, and social distancing requirements. Every city that opened cooling centers in our study had some form of social distancing or mask mandate required for entrance into cooling centers. Many cities traditionally utilized libraries or recreation centers as cooling centers but closed them during summer 2020 due to COVID-19 restrictions. Furthermore, cities such as Columbus, Dallas, and San Jose cut library and parks department budgets to meet COVID-19 budgetary shortfalls leading to reduced operations and staff furloughs (Granberry et al., 2020; Narciso, 2020; Fernandez, 2020). The number of cooling center sites in cities such as New York City, Los Angeles, and Houston were halved in comparison to years before. Additionally, public spaces that might otherwise provide de-facto heat relief, such as malls and museums, were also closed in many cities.

Some cities preemptively opened cooling centers before heat watches or warnings were issued, including San Antonio and Chicago. In Phoenix and El Paso, cooling centers were opened daily for those looking for heat relief throughout the summer, even when heat emergencies were not declared. Non-traditional facilities were used as cooling centers over the summer of 2020. For example, Philadelphia and Chicago both
implemented “cooling bus” programs to leverage their public transportation system’s air-conditioned buses as cooling centers that could strategically be placed in locations that needed cooling access (City of Chicago, 2020; City of Philadelphia, 2021). Phoenix, on the other hand, used their convention center as a larger cooling center with more space availability to physically distance visitors (City of Phoenix, 2020).

However, even when open, attendance in cooling centers was another area of concern for many municipalities. A number of cities reported cooling center underutilization, including Washington DC, Detroit, and El Paso (NPR, 2020; KVIA ABC-7, 2020; AllHunt, 2020). During a four-day heatwave spanning Labor Day (Sept 3–6, 2020), slots in the Los Angeles’s six cooling centers averaged under one-third utilization, with many community outreach volunteers citing poor walkability or lack of transportation options to cooling centers as key reasons for underutilization by vulnerable populations (Alpert ELA, 2020). Previous work found that even in non-pandemic conditions, less than 10% of houses in Los Angeles and Phoenix were within walking distance of an official cooling center (Fraser et al., 2017). Reduced openings because of COVID-19 restrictions significantly reduced geographic accessibility to cooling centers, exacerbating these accessibility challenges.

Cooling center attendance could also have decreased because of reduced programming at cooling centers that would have traditionally helped to attract visitors. For example, although cooling centers were often still open at libraries, recreation centers, senior centers, or park buildings during summer 2020, many ceased programming and standard services (e.g., book browsing at libraries). Significant restrictions of allowed usage for designated cooling centers, such as one-hour per person per day limits in Fort Worth (NBC 5 Dallas-Fort Worth, 2021), or opening hours limited to before afternoon heat such as in Dallas (Jimenez, 2020), could have also dissuaded people from using cooling facilities offered.

3.2. Alternative cooling options

Pools and beaches have traditionally been a key aide for citizens to beat the heat in the past and reported heavy usage on hot days, even despite concerns about COVID-19 (Levin and Ho, 2020; Reimann, 2020). However, COVID-19 related public health restrictions drove many cities to close these alternative cooling facilities. The same budgetary cuts that reduced cooling center availability also impacted the ability for cities to open alternative cooling facilities. For example, the Seattle Parks and Recreation department prioritized utilizing staff resources to provide outdoor lifeguarded beaches rather than their pools (Morrison, 2020). Financial and human resource limits also slowed reopening, as in Jacksonville, Florida, where the gradual reopening of city pools was largely driven by staffing shortages for pools (Jimenez, 2020), could have also dissuaded people from using cooling facilities offered.

Spraying features, such as showers and sprays at parks, interactive fountains, or spray grounds, were another major component of cooling plans in many cities. The relatively low public health risks of opening splashpads, despite reduced municipal staffing and budgetary constraints, likely drove the decision for 5 cities (New York City, Chicago, Philadelphia, Dallas, Boston) in Table 1 to reopen spraygrounds despite some form of limitation on public pools. Spraying resources were a more dispatchable service in comparison to pools. Chicago reopened splashpads specifically during the heat wave to protect health (City of Chicago, 2020) New York City’s Department of Environmental Protection and Fire Department New York worked to proactively install 320 fire hydrant spray caps in zones found to have high heat vulnerability with the goal of maintaining less than a quarter mile distance between spray features or cooling resources (Office of The Mayor of New York City, 2021).

3.3. Financial assistance and individual cooling resources

The economic constraints and restrictions caused by COVID-19 intensified household energy insecurity, and caused people that were already household energy insecure to become more susceptible to both heat and COVID-19 (e.g. poor ventilation leading to both warmer buildings and increased COVID-19 exposure). (Quansah et al., 2021) Energy insecurity intensified because of the COVID-19 pandemic due to the direct impact of household lost wages due to COVID-19 positive members, unemployment following COVID-19 related public health closures and/or fears of contracting the virus, and other factors placing financial hardships on families (e.g, lack of childcare) (Memmoit et al., 2021) These conditions made it even harder for the energy insecure to install new air conditioning or other cooling systems, and/or afford the costs of operating cooling systems.

Many cities in 2020 had services that provided free air conditioners and box fans to the elderly and vulnerable. New York City’s $55 million initiative to provide 74,000 air conditioning units to vulnerable populations was the largest (Office of The Mayor of New York City, 2021). Most other programs were significantly smaller or relied on community donations (e.g. Houston, San Diego). It is important to note that even when cooling infrastructure is available in households, it is not a guarantee that people will use it due to the high electricity costs (Hansen et al., 2011). Thus, utility assistance and utility shut-off bans are also key policy levers that can be used to make cooling resources affordable and accessible. We found that all 25 of the cities studied here had some form of moratorium on utility disconnections throughout the summer of 2020. However, some moratoriums ended before the summer heat ended. Furthermore, these moratoriums on shutoffs did not reduce the accumulation of financial stress on COVID-19 impacted families. Many families were still likely to avoid the use of air conditioning and/or allow indoor temperatures to reach unsafe levels due to concerns over future financial burdens, as has been found in pre-pandemic studies of household energy insecurity (Berry, 2015; Graff and Carley, 2020).

The federally funded Low Income Home Energy Assistance Program (LIHEAP) program (Health and Human Services, 2020) is an important component for reducing energy insecurity, with households who receive LIHEAP money reporting significantly improved health and economic outcomes (Frank et al., 2006). In years past, only 20% of eligible households were able to be funded through the program, but the Coronavirus Aid, Relief, and Economic Security (CARES) Act of 2020 (Coronavirus Aid, Relief, and Economic Security Act, 2020) released an increased $900 million in supplemental funds for LIHEAP (Health and Human Services, 2020). However, many of these funds became available well after the summer of 2020, and thus, may not have been effective in offering resources to help vulnerable residents.

Despite efforts to improve LIHEAP program accessibility, persistent barriers continue to exist. For example, vulnerable populations require knowledge of these programs, the resources to apply (i.e. internet for online applications), and in some cases, help from experienced professionals to navigate the application process.

4. Discussion

The year 2020 tied with 2016 as the warmest year on record, according to the National Weather Service, based on global average surface temperature. However, the record heat in 2020 came during a La Niña year, when a cooling effect would be expected, as opposed to the 2016 El Niño year, when a heating effect would be expected (Voosen, 2021) In the United States, this translated to record high average temperatures throughout many cities such as Chicago, Illinois; Phoenix, Arizona; and New York City, New York. State health officials in Arizona
found that 467 heat-related deaths occurred in 2020, far exceeding the previous record of 283 heat-related deaths reported in 2019 (Fox, 2020). Record temperatures were concurrent with increased infections of COVID-19 throughout the summer of 2020. From June 1st to July 31st, 24% of United States counties and 63% of the U.S. population were designated as COVID-19 high-incidence counties (i.e., >100 weekly cases and increases in cases in the preceding 3–7 days) (Oster et al., 2020). Fig. 1 illustrates (a) Daily Maximum Temperatures and (b) week-averaged daily COVID-19 cases per 100,000 persons reported throughout the period of April 2020 to September 2020 for the counties containing the 25 largest municipalities in the United States investigated in this study. Highlighting case rates during days when temperatures are over 90 degrees Fahrenheit highlights the high concurrency of COVID-19 with high temperatures (Fig. 1c). In ten cities, forty or more degrees of temperatures over 90 degrees coincided with high-incidence of COVID-19 (i.e., El Paso: 84 coincident days, Houston: 81, Dallas:69, Phoenix: 66, San Antonio: 65, Austin: 60, Fort Worth: 60, Jacksonville: 56, Oklahoma City: 49, Charlotte: 40). While these relationships are not causal, there is evidence to suggest that increased temperatures may have increased the spread of COVID-19 as a result increased congregation indoors (Liu et al., 2020). Regardless, outbreaks during these periods made executing heat response plans more difficult due to social distancing protocols.

These health impacts were not unique to the year 2020. In 2021, a heat wave in the Pacific Northwest of the United States brought record breaking temperatures over five days that resulted in an estimated death toll of 800 across the region (Serna et al., 2020). The unique challenge of managing both COVID-19 and extreme heat continued to place stress upon communities. Hospital systems were overwhelmed, with waiting times as long as five to seven hours, especially during the early afternoons (Money and Serna, 2020). Limited access to cooling as well as COVID-19 related social isolation played a major role in adverse heat health effects, especially in the South and the West US (Smith, 2020). As the US and other countries face a future of COVID-19 as a potentially endemic disease, creating effective strategies to respond to extreme events in the context of infection disease outbreaks is increasingly important.

Extreme heat events and COVID-19 pandemic concurrent events were not isolated from other climate-related risks. In California and Arizona, a prolonged heat event in August 2020 induced record-breaking temperatures and increased fire danger (McKeever et al., 2020). Combined with lightning strikes and high wind gusts, hundreds of wildfires sparked across the state of California and combined to form the August Complex Fire, the largest wildfire in California history (Browning et al., 2020). The fire resulted in one million acres burned with several hundred structures destroyed, tens of thousands of residents forced to evacuate, and multiple injuries and deaths (Graff and De Guzman, 2020). Additionally, at one point, the wildfires led to the worst measured air quality worldwide (Samenow and Cusick, 2020). These compounding risks created strained conditions for medical care. Fire, heat, electricity shutoffs, and poor air quality forced the evacuation of some hospitals and prevented some COVID-19 testing sites from opening (Haines, 2021; Centers for Disease Control and Prevention, 2020). Similarly, moisture leftover from the remnants of Hurricane Laura combined with late summer sunshine to produce heat index values of 105 degrees or greater across much of the Mid-South. Over 300,000 customers in Louisiana and Texas lost power after Hurricane Laura inflicted major damage to infrastructure (County of Los Angeles Department of Public Health, 2020). The loss of electricity and heat led some hospitals to evacuate (Gray, 2020).

These compound crises underscore a key challenge in risk-based approaches: risk-management of compound events requires understanding the probability, severity, and consequence of numerous threats and the failures those threats could cause on complex and interconnected infrastructure systems.

Many of the same strategies for heat-adaptation, such as cooling shelters, are transferable to other climate disasters, such as wildfire and post-hurricane shelter requirements. These congregate sheltering solutions provide efficient ways to protect public extreme weather but pose major public health risks during a contagious pandemic. The impact of COVID-19 on heat-adaptation strategies provides insight into how we can prepare for future coupled pandemic-climate events. Many of the same racial inequities that constrain access to cooling resources have also constrained access to health care services, such as vaccinations (Klieneberg, 2018). Developing methods to spatially allocate congregate resources, such as cooling centers, could help cities to more quickly respond and adapt to new compound challenges.

There are also major lessons that were learned during the summer of 2020 that public health departments can draw from in developing best practices for designing future heat response plans in the context of a circulating, highly transmissible disease like COVID-19. The on-the-ground challenges of opening cooling centers while maintaining adequate social distancing was a key challenge for the emergency response community. While Interim CDC guidance has suggested new social physical distancing, air filtration, cleaning, and personal protective equipment protocols to operate cooling centers safely (Ebi and Sementa, 2008), operators at a state and local level also developed their own guidelines and best practices ranging from individual screening questions to rules about food delivery, masking, and re-entry (City of Phoenix, 2020; Chen et al., 2018). While congregate solutions like cooling centers were limited by social distancing requirements, non-congregate solutions allowed better access to cooling resources by using a high number of smaller, more distributed resources. City buses, for example, have played multi-purpose roles throughout the pandemic by being a mobile resource that promotes social distancing by increasing the number of available resources and bringing services directly to those who need it. Beyond extreme heat, buses played an important role as mobile wifi-hotspots to provide internet access for school children (U.S. Energy Information Administration, 2020). As urban systems start to integrate new distributed technologies, such as rooftop solar electricity, electric vehicles with vehicle-to-grid-functions, and microgrid technologies, emergency management departments have an opportunity to develop agile strategies that can move life-saving resources to vulnerable populations during adverse events.

We found that the cities that were most successful in providing access to cooling resources utilized resources beyond traditional public health and emergency management departments. For example, prioritizing often overlooked components of urban infrastructure such as libraries and pools was integral in continuing to provide heat resources to the public during EHEs in 2020. Informing vulnerable populations of and helping them reach key services were also critical aspects of successful heat-resilience strategies. The elderly and other heat-vulnerable populations were significantly more likely to seek out these heat-resources during extreme heat events because of the role libraries, pools, and parks play in civic life (Klieneberg, 2002; Buckee et al., 2020). Engaging stakeholders across different city departments enabled new strategies that leveraged diversified, distributed resources that were already integrated into communities, such as public transportation and schools. City departments can also work with grassroots actions undertaken by business, community leaders, and organizations to identify options that reflect their options and concerns (Vargo et al., 2016).

A large breadth of new data sources and analytical methods can be leveraged to identify vulnerable populations beyond traditional demographic factors, in order to target and optimize heat response strategies. Recent research illustrates how residential smart meter data can be used to detect whether a household uses an air conditioning unit (Vahmani et al., 2016). Given that Advanced Metering Infrastructure is now abundant, particularly in densely packed cities, utilities could use these data to identify heat vulnerable populations (Haines et al., 2006). Mobility data from cell phones has been a key source of data for the influence of travel on COVID-19 spread (Olson and Toprani, 2020). These data could be used to help to better quantify the de-facto usage of
cooling resources and identify sites for cooling centers. As physical access to cooling resources improves, the heat vulnerable will need better access to information about what de-facto or de-jure cooling facilities are available and accessible. One strategy to improve access to cooling access may be to add whether buildings have air conditioning to the results of search engine (e.g. Yelp, Google Maps, etc.) or on public websites to help disseminate information about how and where low-cost air conditioning access is available.

In the long term, cities can also work to reduce the likelihood of extreme temperatures. For example, city planning to require cool pavement, energy efficient buildings, and green infrastructure to combat the urban heat island may help to reduce the magnitude of climate impacts faced by residents (Anon, 2021i; Olson, 2020). Large scale policy initiatives to mitigate climate change may help in reducing more frequent, more severe, and longer lasting heat waves experienced by cities (Guthertz, 2020). However, cities must also build in institutional and financial support systems to improve the resilience of cities by increasing access to cooling resources as urban environments warm.

5. Conclusion

The COVID-19 pandemic disrupted the day-to-day operations, health infrastructure, and economies, of cities throughout the world, exacerbating the already difficult challenge of adapting to a climate-change exacerbated climate hazards. Given the growing frequency, intensity, and duration of EHEs, it is likely that future management of EHEs will require navigating two simultaneous challenges in the future. Our analysis explored how cities around the United States changed their EHE-response strategies to meet the unique conditions created by the COVID-19 pandemic.

Our analysis found that EHE-response strategies were impacted by the COVID-19 pandemic not only by policies to enact limited the spread of COVID-19, but also the economic and staffing limitations induced by those pandemic-related public health restrictions. We found that the cities most able to provide resources to residents leveraged resources beyond traditional public health and emergency management departments. Our work underscores that evaluating multipurpose uses of physical infrastructure and developing improved analytical tools to identify the vulnerable will be a critical step to enabling improved responses to complex compound challenges.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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