Spring 5-2020

The Impact of Extreme Heat on Environmental Justice Communities in California: Assessing Equity in Climate Action Plans

Karishma S. Becha
University of San Francisco, karishma.becha@gmail.com

This Master's Project

The Impact of Extreme Heat on Environmental Justice Communities in California:

Assessing Equity in Climate Action Plans

by

Karishma Becha

is submitted in partial fulfillment of the requirements

for the degree of:

Master of Science

in

Environmental Management

at the

University of San Francisco

Submitted:	Received:
...................................………..	................................…………
Karishma Becha Date	Stephanie Siehr, Ph.D. Date

Abstract

Climate change projections suggest extreme heat events will be more frequent over the next few decades. Extreme heat has both negative environmental and social impacts as it affects energy security, public health by increasing the risk of heat-related illnesses and stresses food and crop supply through prolonged droughts. The impacts of extreme heat will also disproportionately affect communities of low economic status. Because of this, there is a need for better climate action plans that can adapt to and mitigate the impacts brought upon by extreme heat that does not disproportionately impact vulnerable communities. This research analyzed local government Climate Action Plans of three cities in California with environmental justice communities to determine if appropriate adaptation and mitigation measures are addressed. Currently, Climate Action Plans to raise awareness of climate change impacts at a city level and provide measures to reduce risk through adaptation and mitigation measures, however, local government Climate Action Plans seldom address measures focused on socioeconomic status and inequity. Recommendations for cities to have more inclusive adaptation and mitigation measures to extreme heat include: 1) urban heat island data monitoring and measurement to collect, assess, and share demographic data on climate risk, 2) development of well-designed green retrofits and solutions for priority communities, 3) develop a heatwave early warning systems with response plans to reduce the human health consequences of heatwaves, 4) ensure all communities are educated on hazards and risks and have opportunities to engage in disaster preparedness efforts. These recommendations emphasize the importance of inclusivity and minimizing the disproportionate impacts of extreme heat on vulnerable communities. When creating local government Climate Action Plans, cities should continue to pursue innovative and inclusive solutions to the environmental and social impacts of climate change.

Table of Contents

List of Tables and Figures

Introduction

The planet is experiencing a phenomenon known as climate change. The temperature of the Earth is increasing because of the anthropogenic overproduction of greenhouse gases. Greenhouse gases include carbon dioxide, methane, water vapor, surface-level ozone, and fluorinated gases. Greenhouse gases are emitted into the atmosphere through activities such as the burning of fossil fuels for energy and transportation (Fankhauser 2017). However, as the amount of greenhouse gases increase in the atmosphere, global warming occurs from the greenhouse gas effect. The trapping of heat, as a result, has led to many changes in the natural environment, atmosphere, hydrosphere, cryosphere, and geosphere. Since the start of the 20th century, the planet's global temperature has been rising and continues to increase at a fast rate. To put this into perspective, nine out of the ten hottest years recorded have occurred since 2000 (Ahdoot and Pacheco 2015). As greenhouse gas emissions concentration in the atmosphere continues to increase, climate change and its resulting impacts, such as extreme heat, will continue to accelerate in duration and frequency.

Climate change projections suggest extreme heat events will be more frequent over the next few decades (Gingerich et al. 2015, Cayan et al. 2008). Extreme heat is defined as seasonally high temperatures that are significantly hotter and more humid than average (Medina-Ramón et al. 2006). What is considered significantly high temperatures can vary by location as climate zones have different characteristics. For many regions in the United States, extreme heat is defined as a period of days, typically 2 to 3 days, of above-average high temperatures and humidity. In this event, temperatures will be above 90°F as this temperature slows evaporation creating an uncomfortable environment and society (Medina-Ramón et al. 2006, Schnell and Prather 2017). Based on climate projections of greenhouse gas emission concentration, 3 out of 4 people could experience no less than 20 days of presumably deadly heat and humidity levels per year (Mora et al. 2017).

Impacts from extreme heat include both environmental and social effects. Extreme heat causes degraded air quality (Leung and Gustafson 2005), increased risk of wildfire (Addington et al. 2015), prolonged drought (Olen et al. 2016) and water insecurity (Ahdoot and Pacheco 2015) leading to health impacts such as heat-related mortality (Huber et al. 2017, Sheridan and Lin 2014) and morbidity (Sheridan and Lin 2014, Kingsley et al. 2016), impacts on mental health (Basu et al. 2018) and economic effects like stress on energy infrastructure (McCollum et al. 2013). In addition, extreme heat also reduces food security as it stresses crop and livestock production (Baldos and Hertel 2014). The IPCC projected regions with an over 2°C or above increase in temperature will experience decreased crop production of major crops and after the year 2050, regions with low altitude will have the most severe impacts (IPCC 2014). Globally, as more and more people live in cities, expanding the built environment as well as adjusting to growth, resident vulnerability, and exposure to extreme heat is expected to rise. High temperatures coupled with many regions that are rapidly urbanizing contribute to the urban heat island effect which intensifies resident vulnerability and health risk from extreme heat (Tomlinson et al. 2011). Extreme heat and rising temperatures will escalate the urban heat island effect, leading to health and economic problems.

In terms of public health, extreme heat poses a danger to people throughout the United States. Exposure to extreme heat contributed to more than 7,800 deaths in the United States (Medina-Ramón et al. 2006). Extreme heat is projected to impact human health in different ways, including by exacerbating health problems that already exist (White-Newsome et al. 2014). The Centers for Disease Control and Prevention (CDC) conducted studies proving exposure to extreme heat can promote discomfort, fatigue, heat cramps, dehydration, heatstroke, and hospitalizations. Extreme heat also contributes to other health effects such as respiratory disorders and infectious diseases (Gronlund et al. 2016, D'Amato 2002). Additionally, extreme heat negatively affects worker productivity, especially in low- and middle-income communities, resulting in economic consequences such as utility insecurity (Schulte et al. 2016).

Although there are existing actions to decrease greenhouse gas emission concentration, the climate will continue to change as Earth's systems respond to the rising of global temperature, therefore, there is a crucial need for cities and communities to better understand the risk that comes with extreme heat and act to adapt and mitigate the impacts to reduce future environmental, social, and economic risk through urban resilience strategies. Climate urban resilience is the ability to forecast, prepare for, and respond to climate disasters using trends and projections. Improving climate resilience strategies includes assessing how climate change and its impacts will alter climate risks and how to adapt and mitigate these risks.

While extreme heat will affect all communities in California in some way, the effects of climate change and pollution disproportionately impact low-income and ethnically diverse communities (Morello-Frosch et al. 2011). California's communities of color and poor residents are more likely to suffer extreme heat waves and breathe dirtier air. (Morello-Frosch et al. 2009). Residents of environmental justice communities already have less access to health care (Pullen et al. 2010) and activities that promote well-being. Coincidingly, those of lower incomes pay more for basic necessities and have less access to well-paying jobs (Alkon and Agyeman 2011). Because of this, low-income communities and communities of diverse ethnicities are not as capable of mitigating the impacts of a changing climate. Many studies have suggested that low-income communities and the community's ethnic diversity experience the impacts of climate change disproportionately. For example, as climate change worsens and the impacts are not able to be mitigated or prevented, the costs of food production will increase from factors such as food scarcity or water scarcity (Nahlik and Chester 2014). Low-income and minority families will likely end up spending even higher proportions of their income on food, electricity, and water (Economics of Climate Adaptation, Working Group 2009). Resulting in increased vulnerability and health risks, people of color are more likely to live near busy roads and highways, leading to higher risks of pollution-based illnesses and harms (Morello-Frosch et al. 2009).

For city government planners, sustainable development encompasses plans to promote economic development, sustainability, and social equity (Lebel et al. 2006). However, strategies to incorporate all areas are not always achievable. Studies have found, equity is the sector that loses priority in environmental and economic initiatives (Marinucci et al. 2014, Gould and Lewis 2017). In practice where equity is incorporated, priority is given to parts of the community that are of the higher socioeconomic class. In recent history, local planning to adapt to and mitigate the impacts of climate change has gained momentum (Bulkeley, Harriet and Tuts 2013, Bulkeley, H. et al. 2014, Bassett and Shandas 2010). To tackle the issues, local governments have created Climate Action Plans to adopt strategies and creative initiatives for the city's response to climate change. Although the contents vary across each city, Climate Action Plans typically focus on energy efficiency, alternative transportation, and expanding green infrastructure. In terms of equity, local government Climate Action Plans have the capability to address challenges and resulting opportunities.

Motivation

Extreme heat is one of the deadliest impacts of climate change (Kovats and Hajat 2008). Although extreme heat will affect many residents throughout the world, those most vulnerable are those living in disadvantaged communities. California calls for the fairness of disadvantaged communities through the principles of environmental justice (CalEPA 2020). Environmental justice calls for fairness in the development of laws and regulations, no matter the socioeconomic demographic. Development of laws and regulations extend fairness in a community and the resident's area of work, play, and learning. At a local level, this principle of fairness can be executed through Climate Action Plans.

Climate Action Plans are formed to create a roadmap that outlines strategies and initiatives to reduce greenhouse gas emissions (Ray and Grannis 2015). Within these plans, an inventory of greenhouse gases is created to understand the climate impact of a city and areas where the greatest reductions can occur. However, many cities have extended this to create initiatives to combat the direct impacts of climate change through adaptation and mitigation measures. Beyond this, cities with designated environmental justice communities are urged to include initiatives that are inclusive and equitable for those most vulnerable and of a low socioeconomic status through a California statute. As one of the first states in the nation to systematize environmental justice, California pushes leaders to include communities that are disproportionately impacted by climate change and pollution to lift the unfair burden.

As local government Climate Action Plans progress, and cities include equity in the conversation of urban resilience, it is important to mark the initiatives currently in place of cities with environmental justice communities in California to adapt to and mitigate the impacts of extreme heat (Schrock et al. 2015). The goal of this research is to identify what initiatives are currently in place, and if there are any gaps in local government Climate Action Plans through a case study and gap analysis. By identifying the gaps, I provide recommendations to guide city governments to strengthen the implementation of an equitable, effective, and inclusive local government Climate Action Plan.

Research Questions and Objectives

The overall objective of this study is to assess equity in local government Climate Action Plans as they address adaptation and mitigation initiatives to extreme heat in cities with environmental justice communities in California. In addition, the objective is to also provide recommendations to close the gaps and strengthen Climate Action Plans to prevent environmental justice communities from being disproportionately impacted by climate change. To reach this overall objective, the main research questions for this study are:

Do existing local government Climate Action Plans for cities with environmental justice communities address appropriate measures to adapt to and mitigate the impacts of extreme heat? **And** *What management efforts can be made to ensure environmental justice communities are not disproportionately impacted by extreme heat?*

To further understand how extreme heat affects cities and how urban resilience can be used to mitigate and adapt to impacts, I examined the following objectives:

- Understand extreme heat and its impacts
- Analyze local government Climate Action Plans of three cities in California with environmental justice communities
- Identify city community characteristics and vulnerability to extreme heat of environmental justice communities
- Assess gaps within local government Climate Action Plans of cities with environmental justice communities to urban resilience, extreme heat, and equity guidelines
- Develop management strategies to adapt to and mitigate the impacts of extreme heat

Overview of Key Topics

Urban Resilience

Resilience theory has increased in prominence in literature as it provides insight into sustainable management and its relationship to socio-ecological systems (Brown et al. 2012, Nordgren et al. 2016, Lebel et al. 2006) and climate change (O'Brien and Leichenko 2000, Pierce et al. 2011). The theory of socio-ecological resilience is inclusive of the changing climate and changing ecological systems as climate change is nonlinear and, the future is uncertain (Rodin 2014, Tyler and Moench 2012). As urban areas continue to grow and are impacted by climate change, urban resilience has become a common term used in many planning strategies as it is formable to any community type and impact of climate change. This fluidity in the definition of the term allows stakeholders and community planners to find common ground, however, can cause confusion among planners as there is no common metric to compare resiliency plans against others (Folke et al. 2002, Gunderson 2001)

To understand how urban resilience is used throughout peer-reviewed literature, the literature review provided by Sara Meerow, Joshua P. Newell, and Melissa Stults conducted a bibliometric analysis that addresses conceptual tensions that are found in many pieces of literature (Meerow et al. 2016). The common tensions the literature review identifies are equilibrium vs. non-equilibrium resilience; positive vs. neutral (or negative) conceptualizations of resilience; mechanism of system change; adaptation vs. general adapt-ability; timescale of action; and how urban areas are contextualized. Given the conceptual tensions as well as urban resilience definitions found in the top 25 cited peer-reviewed articles (Table 1), the researchers formulated the following definition: “Urban resilience refers to the ability of an urban system and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change and to quickly transform systems that limit current or future adaptive capacity” (Meerow et al. 2016)

Table 1. Definitions of Urban Resilience (Meerow et al 2016)

	Author (year)	Subject area	Citation count	Definition
1	Alberti et al. (2003)	Agricultural and biological sciences; environmental science	212	"... the degree to which cities tolerate alteration before reorganizing around a new set of structures and processes" (p. 1170).
2	Godschalk (2003)	Engineering	113	"... a sustainable network of physical systems and human communities" (p. 137).
3	Pickett et al. (2004)	Agricultural and biological sciences; environmental science	101	"... the ability of a system to adjust in the face of changing conditions" (p. 373).
4	Ernstson et al. (2010)	Environmental science; social sciences	46	"To sustain a certain dynamic regime, urban governance also needs to build transformative capacity to face uncertainty and change" (p. 533).
5	Campanella (2006)	Social sciences	44	"... the capacity of a city to rebound from destruction" (p. 141).
6	Wardekker et al. (2010)	Business management and accounting; psychology	30	"... a system that can tolerate disturbances (events and trends) through characteristics or measures that limit their impacts, by reducing or counteracting the damage and disruption, and allow the system to respond, recover, and adapt quickly to such disturbances" (p. 988).
7	Ahern (2011)	Environmental science	24	"... the capacity of systems to reorganize and recover from change and disturbance without changing to other states ... systems that are "safe to fail" (p. 341).
8	Leichenko (2011)	Environmental science; social sciences	20	"... the ability ... to withstand a wide array of shocks and stresses" (p. 164).
9	Tyler and Moench (2012)	Environmental science; social sciences	11	"... encourages practitioners to consider innovation and change to aid recovery from stresses and shocks that may or may not be predictable" (p. 312).
10	Liao (2012)	Environmental science	6	"... the capacity of the city to tolerate flooding and to reorganize should physical damage and socioeconomic disruption occur, so as to prevent deaths and injuries and maintain current socioeconomic identity" (p. 5).
11	Brown et al. (2012)	Environmental science; social sciences	5	"... the capacity ... to dynamically and effectively respond to shifting climate circumstances while continuing to function at an acceptable level. This definition includes the ability to resist or withstand impacts, as well as the ability to recover and re-organize in order to establish the necessary functionality to prevent catastrophic failure at a minimum and the ability to thrive at best" (p. 534).
12	Lamond and Proverbs (2009)	Engineering	5	"... encompasses the idea that towns and cities should be able to recover quickly from major and minor disasters" (p. 63).
13	Lhomme et al. (2013)	Earth and planetary sciences	4	"... the ability of a city to absorb disturbance and recover its functions after a disturbance" (p. 222).
14	Wamsler et al. (2013)	Business management and accounting; energy; engineering; environmental science	3	"A disaster resilient city can be understood as a city that has managed... to: (a) reduce or avoid current and future hazards; (b) reduce current and future susceptibility to hazards; (c) establish functioning mechanisms and structures for disaster response; and (d) establish functioning mechanisms and structures for disaster recovery" (p. 71).
15	Chelleri (2012)	Earth and planetary sciences; social sciences	2	"... should be framed within the resilience (system persistence), transition (system incremental change) and transformation (system reconfiguration) views" (p. 287).
16	Hamilton (2009)	Engineering; social sciences	2	"ability to recover and continue to provide their main functions of living, commerce, industry, government and social gathering in the face of calamities and other hazards" (p. 109)
17	Brugmann (2012)	Environmental science; social sciences	1	"the ability of an urban asset, location and/or system to provide predictable performance – benefits and utility and associated rents and other cash flows – under a wide range of circumstances" (p. 217).
18	Coaffee (2013)	Social sciences	1	"... the capacity to withstand and rebound from disruptive challenges ..." (p. 323).
19	Desouza and Flanery (2013)	Business management and accounting; social sciences	1	"ability to absorb, adapt and respond to changes in urban systems" (p. 89).
20	Lu and Stead (2013)	Business management and accounting; social sciences	1	"... the ability of a city to absorb disturbance while maintaining its functions and structures" (p. 200).
21	Romero-Lankao and Gnatz (2013)	Environmental science; social sciences	1	"... a capacity of urban populations and systems to endure a wide array of hazards and stresses" (p. 358).
22	Asprone and Latora (2013)	Engineering	0	"... capacity to adapt or respond to unusual often radically destructive events" (p. 4069).
23	Henstra (2012)	Social sciences	0	"A climate-resilient city ... has the capacity to withstand climate change stresses, to respond effectively to climate-related hazards, and to recover quickly from residual negative impacts" (p. 178).
24	Thornbush et al. (2013)	Energy; engineering; social sciences	0	"... a general quality of the city's social, economic, and natural systems to be sufficiently future-proof" (p. 2).
25	Wagner and Breil (2013)	Agricultural and biological sciences	0	"... the general capacity and ability of a community to withstand stress, survive, adapt and bounce back from a crisis or disaster and rapidly move on" (p. 114).

Extreme Heat

Multiple, consecutive days with extreme heat, a heatwave, can pose significant threats to the environment and human health. Global and regional studies have shown that extreme heat events result in increased mortality and morbidity (Huber et al. 2017, Barreca et al. 2016). There are about 11 deadly natural hazards in the United States (Eiser et al. 2012, Smith and Katz 2013). Out of the 11 deadly hazards, extreme heat and its effects account for a plurality of roughly 20% of the mortality (Borden and Cutter 2008). In urban communities, this is partially a result of energy insecurity and heat compounding electrical power systems like air conditioning equipment is being used by many (Vahmani et al. 2019, Hampson et al. 2013). In addition, extreme heat influences agricultural yields. Major crops include soybean, corn, and cotton, all experience a decrease in crop yields and livestock production and reproductive efficiency (Rojas-Downing et al. 2017). Although extreme heat has many detrimental effects, it is not a result of climate change that has received considerable media attention as other impacts (Serdeczny et al. 2016). The reason behind the lack of media can be attributed to extreme heat's lack of visibility and that it also impacts low socioeconomic groups the most (Serdeczny et al. 2016). These groups include seniors, ethnic groups, unhealthy groups, and socially isolated individuals (Borden and Cutter 2008). Using social trends, it is expected that the number of vulnerable populations will increase in terms of how extreme heat will be a hazard as a result of climate change, how many individuals will be exposed, and how populations will be at risk (Pye et al. 2015). An example of a change in vulnerable groups is populations moving to a larger number of older individuals in developed countries (Berisha et al. 2017, Gamble et al. 2013), and individuals are moving away from close family.

Over time, research has been motivated to characterize, understand, and predict the severe impacts of extreme heat because of a growing threat and the increase of severe impacts in different regions. Extreme heat can occur in the midlatitudes from blocking highs or stationary anticyclones that cause a moisture deficit (Notaro et al. 2013, Diem et al. 2017), while over continental regions in the Northern Hemisphere is associated with over 80% of warm temperature extremes which are also associated with blocking patterns (Diem et al. 2017). Other causes of extreme heat are brought upon by climatic systems such as the North Atlantic

Oscillation and the El Nino- Southern Oscillation that adjusts the normal patterns and influences waves of warm temperatures (Cai et al. 2012). In addition to this, extreme heat can be present in high-density urban areas, because of the urban heat island effect (Ramamurthy and Sangobanwo 2016).

Ultimately, the regularity and prominence of extreme heat events are a result of climate change and global warming. The increase in global temperature, global warming is a result of the increased amounts of greenhouse gases in the atmosphere from anthropogenic activities (Medina-Ramón et al. 2006, Katz 2010). The frequency, duration, and intensity of extreme heat events have been analyzed against climate change and global warming studies (Figure 1) (Sussman et al. 2016, Meehl et al. 2016, Kirtman et al. 2013). An example of extreme heat that resulted in above-normal temperatures leading to over 56,000 deaths is a heatwave in Russia in 2010 (Varotsos and Mazei 2019). The record temperatures during this event were five times above July average, rising since preindustrial times (Kirtman et al. 2013). The Representative Concentration Pathway 8.5 emission scenario, which is also known as the business-as-usual scenario, predicts extreme heat with similar duration and temperature anomaly magnitude as that in Russia, are to occur regularly in many regions (van Vuuren et al. 2011). However, in many tropical locations, there will experience a constant extreme heat state where there are very few days that will fall below the extreme temperature level (Hernández-Delgado 2015).

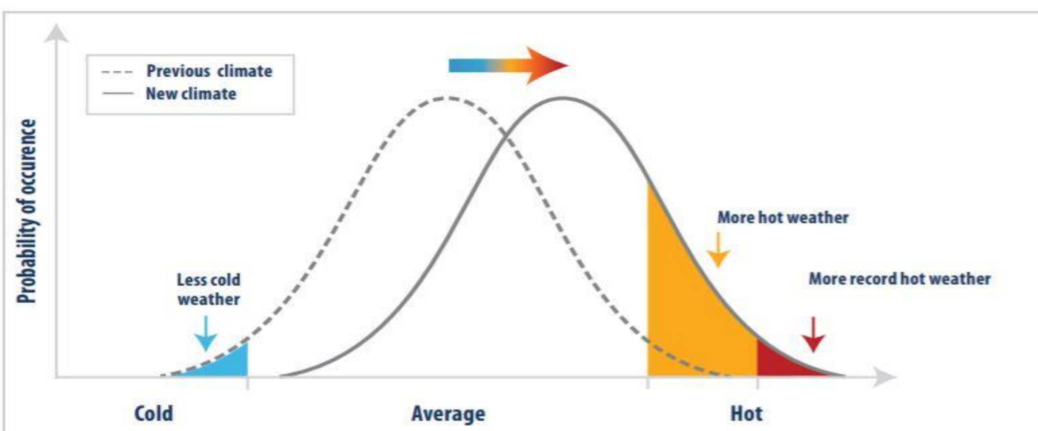

Figure 1. As average temperatures increase, the average temperature of "hot weather" and "record hot weather" will become even hotter (IPCC, 2001)

Extreme heat patterns are influenced by changes in temperature distributions, when they occur, and how often and high event moments. These trends in temperature distributions and high event moments can result in the relationship of different factors. These factors include the radiative effects of increased greenhouse gases, changes in oscillations and circulation, and changes in land-atmosphere interactions (Houghton 2008). In blocking events, such as blocking highs or blocking anticyclones, trends exist as it can correlate circulation anomalies that contribute to extreme heat (Mann et al. 2008). Soil moisture also plays a role in extreme heat events regions with moderate levels of soil moisture are projected to be drier in the summer months, resulting in an increase of surface temperature when paired with changes in circulation anomalies (Melillo et al. 2017, Nearing et al. 2004). Overall, extreme heat events can occur given many factors, including variability in oscillations, circulations, and land-atmosphere interactions, and anthropogenic activities, but exactly how and when the events will occur is uncertain (Horton et al. 2014).

Projections

The United Nations Intergovernmental Panel on Climate Change (IPCC) has concluded "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising of global average sea level" because of evidence that the climate is changing (IPCC 2014). Projections and model simulations show that there are year-round temperatures across North America which will warm approximately 1°–3°C (2°–5°F) for the first half of the 21st century and 2°–3°C (3°–5°F) in the latter part of the 21st century in the eastern, western, and southern edges of the continent (IPCC 2014). Whereas in the high latitudes, there is likely to be more than 5°C (9° F) increase. Many urban areas will experience higher temperatures and an increase in lethal heatwaves. The increase in the frequency of heatwaves as an impact of climate change is evident from 1949 to 1995, and there has been a 20% increase in the number of heatwaves (IPCC 2014). The IPCC projects that heat waves will not only increase in frequency, but also in magnitude and duration in the 21st century in vulnerable parts of the country (IPCC 2014).

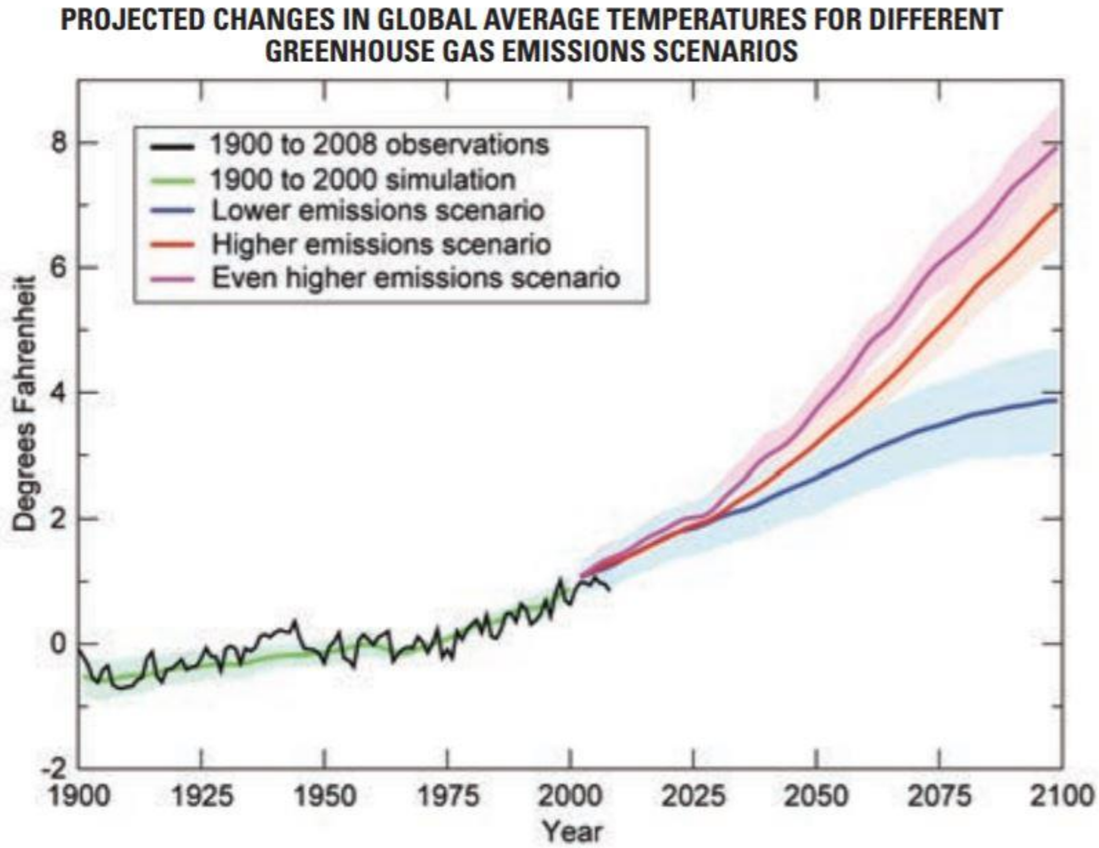

Figure 2. Temperatures are expected to increase given different emission scenarios (IPCC 2001)

Projections from many studies show Earth increasing in global temperatures in the years ahead. Projections are based on observations taken over time, an analysis of trends in greenhouse gas emissions, and climate modeling (Figure 2). Each of these factors is used to determine and understand what extreme heat events will be like in the future, in different regions and in different time frames. The amount of warming and the range of extreme heat depends mainly on the time period in which it occurs and the level of greenhouse gas emissions (Ebi et al. 2016).

Studies expect more prolonged and more extreme heat events as a result of climate change. When using different climate models, each comes to the forecast of the worsening of extreme heat events (Vahmani et al. 2019). Under the scenario that is emissions based, average temperatures have risen 6.3°F (IPCC 2014d), and regions in the United States can expect to experience extreme heat events that will last 10-20 days longer than the regions have in the past (IPCC 2014). A rise in average temperature leads to an increase in extreme heat event severity.

As temperature increases, extreme heat events are more likely to occur as record hot temperatures increase average temperature. Research has found that the occurrence and severity of extreme heat can become normal regional temperatures across regions (IPCC 2014).

Impacts

Heatwaves impact different aspects of life in a city including human health, surrounding nature, critical infrastructure, the economy, and essential services. Exposure to extreme heat can lead to dehydration, heat exhaustion, heatstroke, loss of consciousness, and other medical emergencies. Heatwaves can also exacerbate pre-existing conditions such as cardiovascular disease and respiratory illnesses and have deadly consequences (Bobb, J. F. et al. 2014). Extreme heat can also directly affect infrastructure, for example, by causing road surfaces to melt, making them inaccessible or unsafe. In India during a heatwave in 2016 the heat softened the tarmac on the roads making it difficult for people to cross them (Indian Network for Climate Change Assessment, (INCCA) 2010).

In addition to the direct impacts on human health, heatwaves stretch existing health systems by increasing the number of emergency hospital admissions (Isaksen et al. 2015). Heatwaves also impact the city economy as well as the provision of essential services by reducing the number of hours outdoor workers can be employed safely; reducing productivity in offices without adequate cooling; and impacting sectors such as tourism. In addition, physical infrastructure such as energy systems, water storage, delivery and treatment, and transport are affected by extreme heat both directly and indirectly. For example, demands for water and electricity tend to increase during a heatwave, straining existing systems and potentially leading to shortages (Yates et al. 2013).

Public Health

An increase in temperature and extreme heat events' duration, severity, and frequency will lead to an increase in health problems and mortality (Huber et al. 2017). Many studies have compared models and scenarios to identify the relationship of extreme heat and health impacts and have come to similar conclusions: the number of deaths from extreme heat will increase with climate change and high emission scenarios show a considerable increase of death from extreme heat (Matte et al. 2016, Merte 2017, Vahmani et al. 2019, Medina-Ramón et al. 2006). These studies, however, are estimates and assume death will occur under certain extreme heat circumstances given to research and analysis of trends from previous extreme heat events. An example of this is 100°F day in Chicago as this level of heat is abnormal (Naughton et al. 2002). Over time, with changes in climate change and rising temperatures, demographics, and community types, the relationship between mortality and extreme heat may evolve.

From 2000 through 2009, extreme heat was the leading cause of natural weather hazard related deaths in the United States (Bobb, Jennifer F. et al. 2014). Extreme heat temperatures have resulted in the most weather-related deaths in the United States as the estimated mean annual death toll is about 1500 people over a 30-year span; larger than the combined estimated mean annual death toll from severe weather events such as earthquakes, tornadoes, and floods. Additionally, extreme heat also brings upon other health effects such as heat exhaustion, cramps, rashes, dehydration, and heat stroke (Kovats and Hajat 2008). Existing medical conditions can also worsen and inundate hospitals and medical centers as many residents seek treatment. Existing medical conditions and vulnerability are found in different demographics. Youth, seniors, persons with disabilities, and persons with low socioeconomic status and living in isolation, such as the homeless population are the most vulnerable during extreme heat events (Trombley et al. 2017, Kenney et al. 2014, Anderson et al. 2016). The number of vulnerable populations will also increase because of the number of people living in urban areas or moving to densely populated areas contributing to the urban heat island effect (Habeeb et al. 2015). Most specifically, the number of vulnerable residents in the United States that are 65 years old and older, will continue to increase based on population growth estimates (Gronlund et al. 2016). In addition, these increases will also correlate to changes in medical and health care, transportation patterns and services, innovation when designing urban areas, but are all dependent on population presence and trends (Medina-Ramón et al. 2006).

In addition, extreme heat has contributed to other health conditions that resulted in hospitalizations. For example, during the 2006 California Heat Wave, there were 501,951 hospital emergency room visits, an excess of 16,166 compared to the non-heat wave period.

During heat waves, mortality is attributed to people with cardiovascular and respiratory diseases and illnesses (13-90%) and cerebrovascular illness (6-52%) (Kilbourne 1999). In addition to heat-health risks, heat stress is also a factor in mortality as it is life-threatening, and symptoms need to be treated right away and many are unable to reach emergency departments in time. Studies have exemplified patterns in morbidity and mortality as it relates to heat-health risk. In California, it has been observed that hospitalizations associated with heat risks and admission numbers are most attributed to younger and senior adults, as well as adults that participate in outdoor activities such as working in agriculture or fishing and hunting. (Knowlton et al. 2009) Between 2005 and 2010 in Los Angeles County, the proportion of hospital visits was higher among those that work outdoors during summer heatwave events (Pincetl et al. 2016). Of those working in construction, there was an 8.1% increase in emergency room visits, and 7.9% increase in hospitalizations (Riley et al. 2018). The agriculture, forestry, fish and game, and mining industries experience a 10.9% increase in emergency room visits during a heatwave (Riley et al. 2018). The heat exposure outdoor workers experience increases their chance of heat stroke and heat illness or magnify existing health complications. Indirectly, few studies have shown that many working in outdoor industries also experience low-wages which in turn results in poor living conditions, also contributing to heat-related health risks (Riley et al. 2018). For those that do not work outdoors, in industries such as education, healthcare, and social assistance, there was a 1.3% increase in emergency room visits (Riley et al. 2018).

Intensification of Urban Heat Island Effect

The Urban Heat Island Effect pertains to the occurrence of an increase in ambient temperatures in urban areas and cities compared to suburban areas and rural areas (Santamouris 2015). The extent of the urban heat island effect is dependent on the purpose of layout of the urban areas, what materials are used to build urban areas, weather patterns, and climate conditions, meteorological elements, and morphological, structural, and physical characteristics of cities and urban areas because each of these factors plays a role in how much anthropogenic heat is released (Santamouris 2015, Tomlinson et al. 2011). Compared to rural areas, urban areas, such as cities and/or suburban areas, have less vegetation. With less vegetation, there is less shade and moisture, a factor that keeps urban areas cool. In addition, conventional roofs and pavement in urban areas also have a low albedo, absorbing more energy increasing local temperatures near structures with these features (Yang et al. 2015, Morini et al. 2016). Tall buildings and narrow streets contribute to the urban heat island effect because it reduces airflow trapping heat absorbed from the warmer parts of the day in addition to the heat generated from industry, air conditioning units, and vehicles that run throughout urban areas. These factors also contribute to the impacts of climate change, adding to cycles of the duration, severity, and occurrence of extreme heat events (Ramamurthy and Sangobanwo 2016). Daytime and evening maximum temperatures are also affected in the city and urban areas as the temperature values are higher and cool slower compared to that of rural areas. In the warmest part of the day, the temperature can be 1.8–5.4°F warmer in urban areas compared to regions in its surrounding, however, in the evening, temperature differences can reach 22°F because of daytime heat retention (Bounoua et al. 2015).

Mitigation efforts to minimize the impacts of urban heat in communities have begun in California at regional levels. The California Environmental Protection Agency has initiated efforts to quantify and characterize urban heat islands in California as pursuant to Assembly Bill 296 by creating an Urban Heat Island Index. This index is used to address health impacts as a result of heat, identifying areas spatially where urban heat islands can worsen pre-existing conditions, and collecting information for the CalEnviroscreen tool (Taha 2017, California Environmental Protection Agency 2018) During this process, the urban heat islands and urban heat island index were characterized using existing meteorological modeling (Taha 2017). In conjunction with other data sources, analyses, and models, the urban heat island index will provide additional information as to how heat affects public health.

Energy Insecurity

Energy insecurity can occur when persons in urban areas are using electrical sources to combat the immediate effects of extreme heat events. Summer temperatures increase the demand for energy as it is the lifeline to cooling systems, but the demand concurrently limits the ability for power lines to transmit power leading to energy insecurity and nonreliability. In warmer winter months, the need for heating will decrease, however, this is an indication of a warmer future as a result of climate change (Alexander et al. 2010). In addition to warming winter months, the warming of water bodies and its capacity to absorb waste heat from hydroelectric power will reduce efficiency, adding to the insecurity of energy (Vicuna et al. 2008).

Many studies have defined energy security, and energy insecurity differently. Energy security is the relationship between the availability of natural resources for energy consumption and regional and national security (McCollum et al. 2013). To be able to access and rely on a steady stream of reliable energy is something residents in developed countries have been accustomed too, it also the lifeline of industry and the economy. However, some regions experience an uneven distribution of energy supply which leads to vulnerabilities in infrastructure and population stability. The idea of a consistent or secured energy supply, or known as energy security, is usually used interchangeably. Studies that are conducted around the concept of energy security or energy insecurity focus mainly on policies to address issues without explaining the concept as a whole or creating a standard measurement for analysis. It is because of this that there is inconsistency in studies when analyzing this issue. The International Energy Agency states energy insecurity "stems from the welfare impact of either the physical unavailability of energy, or prices that are not competitive or overly volatile" (IEA 2016) Basically, the concepts of energy availability, cost, and volatility are included in many explanations of energy security. Another study adds the definition by referring to energy security as "the loss of economic welfare that may occur as a result of a change in the price or availability of energy" (Bohi and Toman 2012). In addition to this definition, potential energy security effects that attribute to the loss of economic wellness are grouped in terms of volume of energy movement, cost, and national, military use (Bohi and Toman 2012). Overall, definitions can vary between a focus on availability and economics.

In terms of energy pricing, the International Energy Agency includes in their definition that the cost of energy will be determined by the physical availability of resources to meet demand at a given price, including the risk of energy security (IEA 2016). Alternatively, the European Commission Green Paper "Towards a European Strategy for the Security of Energy Supply" claims: "The European Union's long-term strategy for energy supply security must be geared to ensuring, for the well-being of its citizens and the proper functioning of the economy, the uninterrupted physical availability of energy products on the markets, at a price which is affordable for all consumers (private and industrial)" (Europea 2000). The DG Energy and Transport of the European Commission defines energy security "as the availability of energy at all times in various forms, in sufficient quantities, and at reasonable and/or affordable prices" (vd Linde 2004).

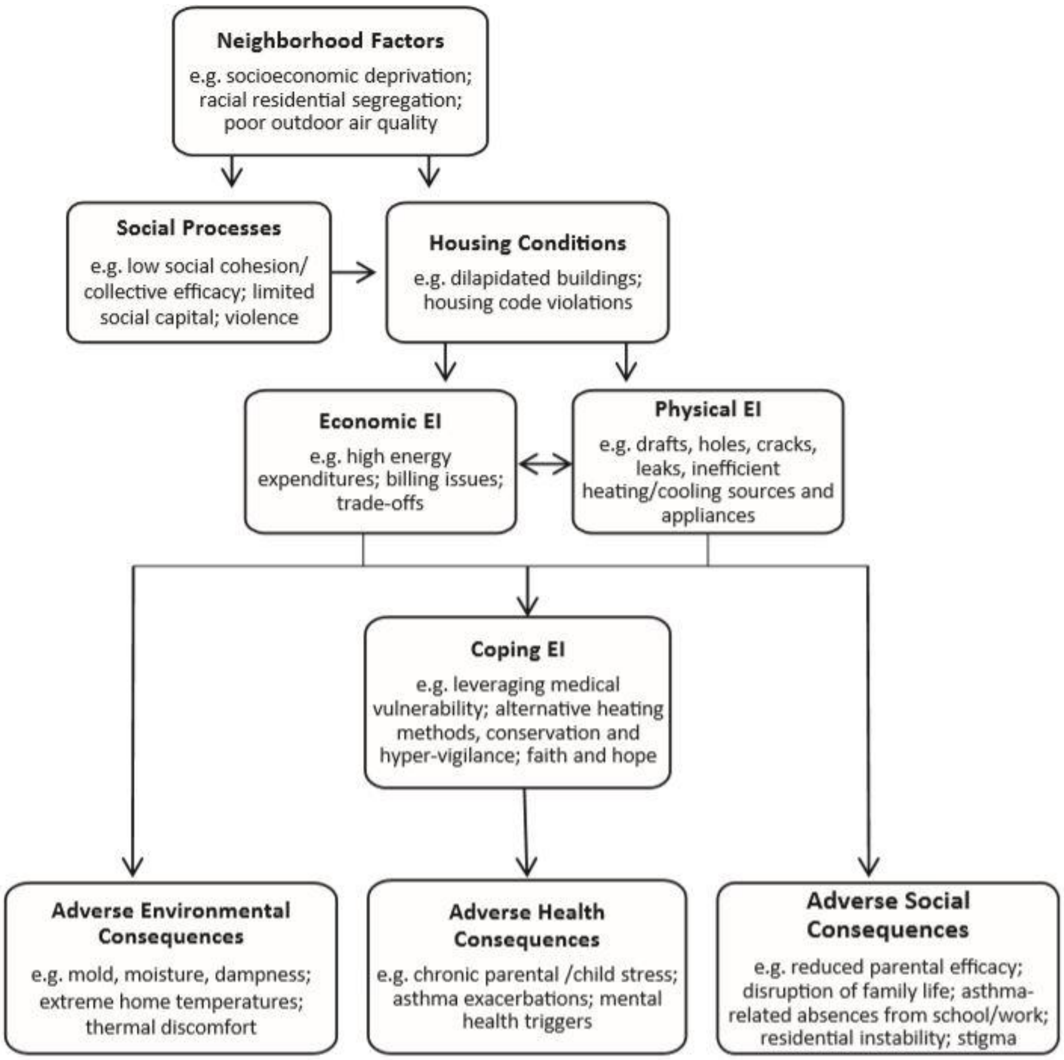

Figure 3. Energy insecurity: a pathway to disease and disadvantage (Hernandez 2016)

In addition to their definition, The European Commission Green Paper commented that having access to energy is important in terms of social and public health concerns. Over time, the cost for heating and cooling residential and commercial buildings will increase and will eventually create a disparity among social classes because being able to afford a commodity, like energy, is uncertain. Economic ratios to estimate the energy cost burden on residents in developed countries are represented as limited household income too high energy disbursement (Burillo et al. 2019, Vahmani et al. 2019). The energy burden and limited fuel availability occur when disbursement exceeds 10% of a resident's household income, and this is shown most prominently in households near the poverty line as many are unable to pay for the service (Vahmani et al. 2019). However, this is not including factors that may also contribute to this such as types of house and energy usage behavior.

The term energy insecurity has also been used to understand its relationship to social disadvantages, negative health impacts, and additional insecurities in the field of the environment and economics, especially toward residents with low socioeconomic status. Studies have shown African American demographics experienced the most economic energy insecurity while Latino and Asian immigrants were the least affected (Figure 3) (Hernández et al. 2016). Studies have also shown health hardships have also been linked to energy insecurity (Cook, J. T. et al. 2008). Youth that reside in homes with an insecure energy source is also subject to other dangers (Cook et al. 2008). These dangers include lack of food and malnutrition, the need for medical care, poor health rates, and slow development (Cook et al. 2008).

Environmental Justice and Equity

To begin to understand why the environmental justice movement is important, it is imperative to understand that it originated from the response of environmental racism and the fear instilled in community members when their lives, health, and well-being are being disproportionately put at risk because of their race, ethnicity, income and other socioeconomic factors. Environmental racism became known in the political and academic world in 1982. At this time, civil rights activists organized and protested the dumping of 120 million pounds of soil contaminated with polychlorinated biphenyls (PCBs) against the state of North Carolina. The dumping of contaminated soils would have taken place in South Carolina's county with the highest proportion of African American residents (Mohai et al. 2009). The protests and awareness stemmed from the dumping of pollutants deemed Warren County as the birthplace of a new social movement that boosted awareness that people of color and low-income communities are facing even greater ecological disasters. Until this, environmental equity was not in the conversation of many environmentalists.

Studies in environmental justice soon became developed as an interdisciplinary body of literature where many researchers started to look at and document the disproportionate impacts of environmental pollution on different demographic groups; this included different social classes and racial and ethnic groups. Presently, additional studies concluded ethnic minorities, indigenous groups, people of color, and low-income groups are exposed to air, water, and soil pollution. In addition to the academics, regulators and policymakers have also discussed and acknowledged environmental justice, environmental racism, and environmental inequality when developing regulations. It is through this growth that a considerable body of literature on environmental inequalities has emerged.

Thus, a substantial body of literature that documents the existence of environmental inequalities in the United States emerged (Mohai et al. 2009). The findings from early studies were later improved and solidified by a sequence of studies focusing on the location of hazardous waste sites. The sequence of studies began with a study conducted by the U.S. General Accounting Office in 1983. The study documented African American communities in the southern United States that were disproportionately exposed to and located near a high number of hazardous waste sites (General Accounting Office 1983). Following the study by the GAO, a regionally study by the United Church of Christ Commission for Racial Justice released a study that documented the discriminatory and unbalanced locations of toxic waste facilities throughout the United States (Ministries et al. 2007). This study concluded that race and ethnicity were the most significant factor in calculating where the toxic waste sites would be located. First coined by Benjamin Chavis in 1982, the executive director of the United Church of Christ Commission defined the term environmental racism. "Environmental racism is racial discrimination in environmental policymaking, the enforcement of regulations and laws, the deliberate targeting of communities of color for toxic waste facilities, the official sanctioning of the life-threatening presence of poisons and pollutants in our communities, and the history of excluding people of color from the leadership of the ecology movements" (Ministries et al. 2007). Thus, environmental racism "refers to any policy, practice, or directive that differentially affects or disadvantages (whether intended or unintended) individuals, groups, or communities based on race or color" (Ministries et al. 2007).

Robert Bullard, also known as the Father as Environment Justice, contributed to the definition of environmental justice by including a remedy for environmental racism. He defined environmental justice as the belief that "all people and communities are entitled to equal protection of environmental and public health laws and regulations" (Ministries et al. 2007) In a 1999 interview, Bullard described "the environmental justice movement has basically redefined what environmentalism is all about. It basically says that the environment is everything: where we live, work, play, go to school, as well as the physical and natural world. And so, we cannot separate the physical environment from the cultural environment. We have to talk about making sure that justice is integrated throughout all of the stuff that we do" (Bullard 1994). Following the origin of the environmental movement and the solidification of the definition, legalistic and governmental consideration arose under the United States Environmental Protection Agency. Under this agency, an official, nation-wide definition was generated that expanded on the principle. As stated by the EPA, environmental justice is "The fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate share of the negative human health or environmental impacts of pollution or environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local and tribal programs and policies" (United States. Environmental Protection Agency. Environmental Equity Workgroup 1992). This definition stands as the official policy and official legal standard to qualify environmental justice groups to receive government assistance and attention, despite changes in the United States' presidential administrations.

Given many organizations and studies, environmental justice can be defined in many ways as it is a multidimensional concept. Because of the many definitions, it is imperative that studies and agencies choose a definition that is the best fit and encompasses the intended implications. As compiled in a study by Carl V. Phillips and Ken Sexton, five fundamental dimensions are used to define environmental justice (Table 2).

Table 2. Five fundamental dimensions inherent to defining "environmental justice" (Phillips and Sexton 1999)

1. Defining Fairness: How is fairness (procedural and/or outcome) defined in relation to environmental decisions?
   - broad participation
   - rules that will on average leave everyone better off
   - changes acceptable to everyone
   - benefits proportional to costs
   - identified group suffers no more than population average
   - benefits according to need
   - all costs distributed evenly across population
   - some combination of these
2. Specifying the Scope of Concern: Which environmental hazards/risks are included (or excluded) as part of environmental justice considerations?
   - noxious facilities (siting, enforcement, and restoration decisions)
   - all environmental hazards (including housing, jobs, etc.)
3. Characterizing Unfairness: How unfair must a situation be to constitute environmental injustice (e.g., magnitude and severity of departure from fair)?
   - objective measures of deviation from a quantitative definition of fair
   - subjective measures of deviation from a qualitative definition of fair
   - systematic patterns vs. single decision
   - persistence over time vs. isolated occurrences
4. Identifying Those Treated Unfairly: Which individuals or groups are the object of environmental justice concerns?
   - socioeconomically disadvantaged
   - racial and ethnic minorities
   - other groups defined by age, health status, geography, etc.
5. Distinguishing the Root Cause(s) of Unfairness: What is the likely cause(s) of apparent unfairness?
   - intentional discrimination
   - political expediency
   - case utilitarianism or risk-analysis calculations
   - neighborhood transition or other voluntary changes

Legal analysis has shown that claims of environmental justice must remain arguable for a variety of reasons. The first of those reasons is that the mainstream environmental movement and early research did not include equality, equity, or social issues in their analysis. It is also debatable that the inclusion of exposure to pollution on communities of color and the working class is involved in studies, or that it should be considered in environmental research (Institute of Medicine (U.S.) Committee on Environmental Justice 1999). In other words, there is not a common agreement among environmentalists that including environmental justice research is needed. Secondly, documenting and proving the presence of a disproportionate impact from pollution on communities of racial and ethnic populations or low-income populations has been difficult for researchers. This is difficult because in many cases, demands provided by the environmental justice communities have been diverted by other skeptical researchers (Bulkeley et al. 2014) Some studies conducted by skeptical researchers have also gained attention, thus stalling the inclusion of social issues in environmental matters. Many studies have converted to debates on the best way to solve problems during research because many policies are based around the findings of the research. Another reason the studies behind environmental justice are arguable is there has not been much documentation on how environmental injustice can be addressed correctly to promote social equity through policy and research (Brulle and Pellow 2006). Addressing environmental justice through policy and regulation can be complex and expensive given the communities and industries involved. Making changes to a community can also have adverse effects, locally, regionally, and nationally in terms of economics, social justice, and the environment. For example, a solution to environmental injustice can include the relocation of communities. This can disrupt the local economy given many residents will no longer work and contribute to that community monetarily. It can also disrupt communities socially as many families have settled and rooted themselves in a community; by moving, communities are jeopardizing stability and culture generated from these areas. Without proper research and solutions, it is highly possible another negative outcome can arise (Roberts and Toffolon-Weiss 2001). Although there is a common consensus that exposure to pollutants should be reduced for all, the lack of solutions and guidance to reduce impacts on communities.

Despite the disproportionate environmental harms, disadvantaged communities face as proven by research and environmental justice activist groups, many environmental policies and programs have not addressed the needs of these communities. Programs and policies have instead overlooked these communities or made their overall harm more severe. While there has been a strong push for investment in environmental resources and the fight against climate change, many of these types of programs ignore the socioeconomic realities and needs of low-income communities. Many of the identified environmental justice and disadvantaged communities have consistently high levels of unemployment, little economic industry, and few opportunities for increasing self-sufficiency (Lave and Seskin 1977).

Many policies in California have evolved to mitigate pollution, however direct help to disadvantaged communities are pending and not solidified in policies today. California's process of implementing cap-and-trade after the passage of Assembly Bill 3240 dismissed advocates' concerns regarding the program's potential harms to low-income communities and communities with ethnic diversity. Advocates reacted by simultaneously pushing back on the development of the cap-and-trade program and seeking creative solutions to mitigate potential harms and create benefits to remedy the deep problems in these communities.

Materials and Methods

Case Study and Gap Analysis

The case study analysis involves the individual analysis and synthesis of the community characteristics, vulnerability, and local government Climate Action Plan compared to The Heatwave Guide for Cities, Characteristics of a Resilient City, and equity principles of three cities with environmental justice communities in California: Oakland, Fresno, and Los Angeles. This analysis will utilize qualitative methods to understand the gaps in local government Climate Action Plans and measures to address adaptation and mitigation efforts to extreme heat. There are limited resources that encompass the three topics collectively in one document, therefore extensive research and collection of sources are combined to create a feature to analyze. A gap analysis conducted for each community will examine and assess the inclusivity and completeness of local government Climate Action Plans for the purpose of identifying gaps.

The gap analysis portion will first identify the main components of a local government's Climate Action Plan in relation to extreme heat events and community equity and compare this to the Heatwave Guidance for Cities guidance document, the Characteristics for a Resilient City guidance document, and Equity by Design: Five Principles guidance document to identify areas the climate action plans are lacking and fill in recommends as provided by the guidance documents.

Selection of Cases

Three cities with environmental justice communities were chosen from communities identified by the CalEPA Environmental Justice Task Force. Originally known as the Environmental Justice Compliance and Enforcement Working Group, the CalEPA Environmental Justice Task Force was created through a mandate for the boards and departments of the California Environmental Protection Agency (CalEPA) to prioritize enforcement and compliance in disadvantaged communities through a multi-agency effort. Funding for this mandate ensures there is a development of initiatives to increase compliance where it will have the greatest enhancement in disproportionately impacted communities (CalEPA 2020). The vulnerable communities are burdened and disproportionately impacted by many sources of pollution and are identified using environmental justice considerations and programs such as CalEnviroScreen. Communities that are disproportionately impacted by pollution in California have voiced concerns of exposure and limited enforcement of polluting facilities in neighborhoods, therefore policies and programs prioritize community consideration when discussing rules and regulations.

The following are three cities chosen for the analysis and their relationship to the CalEPA Environmental Justice Task Force:

Fresno

The Environmental Justice Compliance and Enforcement Working Group used data and observations from CalEnviroScreen, a California Communities Environmental Health Screening Tool, to identify pollution burdens in Fresno, California. The Working Group identified and coordinated the priorities of multiple agencies to review existing enforcement and compliance efforts.

Oakland

The Environmental Justice Task Force worked with local organizations such as West Oakland Environmental Indicators Project and Communities for a Better Environment and residents of Oakland, California to identify and learn about local environmental issues and concerns. Using this communication, the EJ Task Force was able to conduct enforcement inspections and provide compliance assistance to industrial facilities using a multi-agency approach. Enforcement reports were discussed and presented to the community with strategies to continue to address issues at the completion of the initiative.

Los Angeles

The Environmental Justice Task Force created community consultation tours and partnered with enforcement agents from CalEPA's boards and departments as well as regional agencies to develop priorities and share information on enforcement initiatives. Using a multi-agency approach, the Task Force was able to target specific areas. Upon completion, compliance assistant events were held, and results were reported to the community.

Metrics to Assess Community Characteristics and Vulnerability

Because each city's geographical location and demographics vary from each other, I identified the city's characteristics and assessed vulnerability using tools from the State of California and involved agencies. Collectively, these tools are used to identify environmental burdens brought upon by extreme heat.

CalEnviroScreen

The California Environmental Protection Agency released the California Communities Environmental Health Screening Tool or CalEnviroScreen which is a screening tool to identify vulnerable and disproportionately impacted communities in California. The screening tool considers both pollution exposure and population vulnerability in assessing the potential for cumulative impacts. In order to identify a community's characteristics in this analysis, CalEnviroScreen is used to assess the expanse of geographic and racial and ethnic disparities when looking for cumulative environmental health impacts. The tool provides a clear, accessible, and science-based method for identifying disproportionately impacted environmental justice communities.

This source will be used to determine population characteristics. The maps, shown as figures, are representative of CalEnviroScreen's Population Characteristics scores. Population Characteristics are a representation of biological factors, health, or community characteristics. The 8 indicators used to develop the scores are asthma, cardiovascular disease, low birth weight, education, housing burden, linguistic isolation, and poverty. This all leads to how vulnerable a population is. The scores are made from indicators from components of the Sensitive Population and Socio-Economic Factors of CalEnviroScreen. The analysis will utilize the CalEnviroScreen as a metric to identify a community's vulnerability.

CalEPA Urban Heat Island Index

To identify extreme heat impact risk in environmental justice communities, CalEPA's Urban Heat Island Index is used to examine and define the characteristics of urban heat islands as well as assigning a score based on atmospheric modeling. This index was created because of AB 296, Chapter 667, Statutes of 2012 developed by the California legislature to examine the characteristics of an urban heat island, and to create a map to show where it is most intense by creating an index. The analysis will utilize the Urban Heat Island Interactive Map as a metric to identify the intensification of extreme heat.

Cal-Adapt

To identify extreme heat event frequency, timing, and duration, Cal-Adapt provides data and graphs to view this information. This tool has been developed by the University of California, Berkeley's Geospatial Innovation Facility with funding and advisory oversight by the California Energy Commission. For this analysis, the tool "Extreme Heat Days & Warm Nights" and "Warming and Cooling Days" is used as a metric to analyze a community's vulnerability to extreme heat events. Within the tool, 5 different data sets will be used to identify community vulnerability. The first data set shows frequency of extreme heat days and warm nights. Another shows the timing of extreme heat days and warm nights by showing the number of days between April and October where the daily maximum temperature is above the heat threshold. In addition, data sets also show the frequency of heat waves and the maximum duration of extreme days and warm nights where heat waves last over 4 days. The final data set is that of cooling degree days which shows the number of cooling degree days in a community's location in a certain time period.

Selection of Guidance Documents

To identify the gaps within local government Climate Action Plans the following resources are used to address proper identification and responses to extreme heat, environmental equity, and climate resiliency measures. The following guidance documents were chosen because there is no comprehensive guidance document and framework that encompasses extreme heat, equity, and urban resilience. The following guidance documents have been recommended and included in sources such as the U.S Climate Resilient Toolkit, United Nations reports, and the U.S Environmental Protection Agency's Urban Resilience report. The overarching objectives and clear guidelines and explanations are why they were chosen for this analysis.

The Heatwave Guide for Cities

The Heatwave Guide for Cities is a guidebook created by The International Federation of Red Cross and Red Crescent Societies and in collaboration with 25 partner institutions for city officials to understand, prepare for, and reduce the impact of extreme heat events. This guidebook provides a dependable summary of initiatives and information for technical staff within city governments that includes effective management and leadership strategies, key skills and roles of city government, city-specific extreme heatwave risks, creating climate-sensitive designs and public information campaigns, preparing for the heat season, early warning systems, during extreme heat event guidance, and post extreme heat event guidance (The International Federation of Red Cross and Red Crescent Societies 2019).

The Heatwave Guide for Cities provides 5 main objectives. The first objective is to understand heat risk. Cities are able to understand heat risks by listing the factors that contribute to it. This includes identifying daytime and nighttime maximum temperatures as well as humidity levels to pick an extreme heat threshold. Cities should also consider existing heatwave definitions to create one relevant to their local climate. The next objective is to prepare for the heat season and imminent heatwave. Cities can prepare for the heat season by coordinating among many departments such as the health department, emergency management, and meteorological services to create a heat action team. Preparation also occurs all year as cities should engage the community, map vulnerable areas, create a public messaging system, and high vulnerability index. Prior to a heatwave, cities should also review emergency plans, alert emergency services, evaluate conditions of high-risk communities, ready cooling centers, and address risk perception. The next objective is to develop a heat-health early warning system. The components of a basic heatwave early warning system include a definition of a temperature threshold, warning mechanism, communication of temperature and impacts, action to reduce risk, and evaluation of efficiency. The next objective is to reduce heat risk during a heatwave. Cities can reduce risk by conducting public awareness campaigns, increase access to water, plan for energy demand, organize outreach to vulnerable populations, create cooling centers, create a hotline to provide guidance, limit outdoor activity, and enhance emergency management systems. The final objective is to create a process for an after-action review. Cities can create a review process that is conducted shortly after a heatwave with many stakeholders and involved parties. In this review, a few questions should be answered such as: what was planned, what happened, what worked well, and what can be improved (The International Federation of Red Cross and Red Crescent Societies 2019).

Characteristics of a Disaster-Resilient Community: A Guidance Note

The Characteristics of a Disaster-Resilient Community was commissioned by ActionAid, Christian Aid, Plan UK, Practical Action and Tearfund, together with the British Red Cross/International Federation of Red Cross and Red Crescent Societies and has received funding from the UK Department for International Development (DFID) for disaster risk reduction (DRR) initiatives, and to support the promotion of the Hyogo Framework for Action

(HFA). This guidance document was created to identify characteristics of community resilience in line with national and international standards and work from the United Nations' led agencies. The Characteristics are to be used to support communities in preparing for hazard impacts and ensuring they are instilled with skills and resources to adapt to and mitigate impacts. It also sets many elements of resilience and some ideas for cities and communities to measure progress.

The Characteristics consists of a series of tables that identify the characteristics of a disaster-resilient community with guidance on how to use them. The characteristics are organized under five thematic headings based on a framework developed by the UN International Strategy for Disaster Reduction (UN ISDR): the Hyogo Framework for Action 2005-2015 (HFA). The Thematic Areas include governance, risk assessment, knowledge and education, risk management and vulnerability assessment, and disaster preparedness response (Twigg 2009). As the Thematic Areas are broad, they are additionally divided into the subsections of components of resilience which are a set of activities that contribute to resilience planning, characteristics of a disaster-resilient community are strategies that are more specific resilience strategies, and characteristics of an enabling environment which motivates actions resilience.

Equity by Design: Five Principles

The Center for Urban Education, by the Association of American Colleges and Universities, has created a guidance document to list five interconnected principles highlighting equity concerns that can be used in sustainable development and urban resilience planning. This is a supplemental resource to America's Unmet Promise: The Imperative for Equity in Higher Education. This guidance document was created to ensure equity by design in education settings, however, each principle represents challengeable goals that can be adapted and molded to other sectors (Bensimon et al. 2016). In this analysis, the equity principles will be used to identify inclusivity elements in local government Climate Action Plans include: 1) clarity in language, goals, and measures is vital to effective equitable practices, 2) 'equity-mindedness' should be the guiding paradigm for language and action, 3) equitable practice and policies are designed to accommodate differences in the community types, 4) enacting equity requires a continual process of learning, disaggregating data, and questioning assumptions about relevance and effectiveness, and 5) equity must be enacted as a pervasive institution- and system-wide principle (Bensimon et al. 2016).

Comparative Analysis

The comparative analysis portion of this study will compare each city's vulnerability to extreme heat, as well as their local government's Climate Action Plan's ability to meet the objectives outlined in the guidance documents.

Case Studies

Fresno

Community Characteristics and Vulnerability

In 2018, Fresno, CA had a population of 530,000 people with a median age of 31.5 and a median household income of about $50,000 (United States Census Bureau 2019). The population grew 0.5% from 2017 and 2018 to 527,000 to 530,000. 49.5% of Fresno's residents are Latino or Hispanic and 13.9% are Asian, leaving the city's racial demographic almost over 70% non-white (United States Census Bureau 2019). Median household income in Fresno grew 2.5% from $48,600 to $49,000 from 2017 to 2018 (United States Census Bureau 2019, U.S Bureau of Labor Statistics 2020, California Environmental Protection Agency 2018). Fresno residents also have a rising unemployment rate. According to the Bureau of Labor Statistics, Fresno had 8.9% unemployment in February 2019 and 10.8% unemployment in March 2020 (U.S Bureau of Labor Statistics 2020). Fresno is also environmentally burdened as there is air pollution from surrounding freeways, poor water quality, and pesticide exposure. According to CalEnviroScreen, much of the city falls into the 80 to 90 percentiles (Figure 4) (California Environmental Protection Agency 2018).

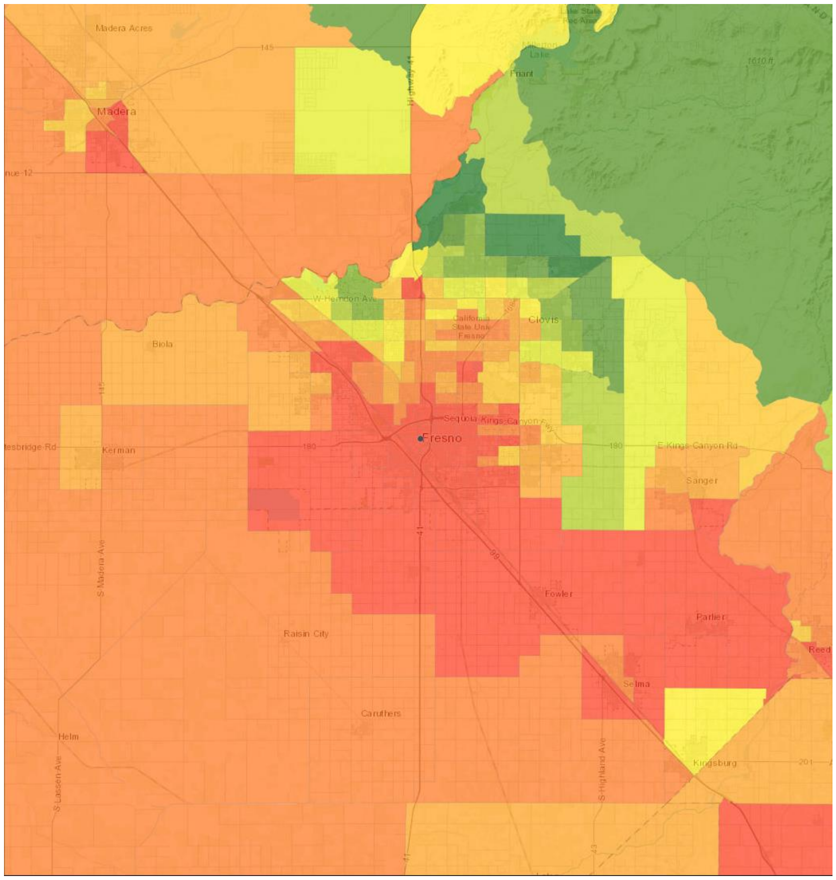

Figure 4. CalEnviroScreen: Fresno, Ca (CalEnviroScreen)

In Fresno, California, extreme heat is expected to increase in frequency and duration. Typically, the average temperature ranges from 39°F to 99°F and is rarely below 31°F or above 106°F (University of California and California Energy Commission 2020). The threshold temperature of what constitutes extreme heat is 106°F (University of California and California Energy Commission 2020). The maximum duration of extreme heat days is expected to increase for the foreseeable future (Figure 5). Between 1961 and 1990, there was an average number of 2.4 days in the longest heatwave (University of California and California Energy Commission 2020). From 2050-2099, the average number of days in the longest heatwave will be 13.1 days (University of California and California Energy Commission 2020).

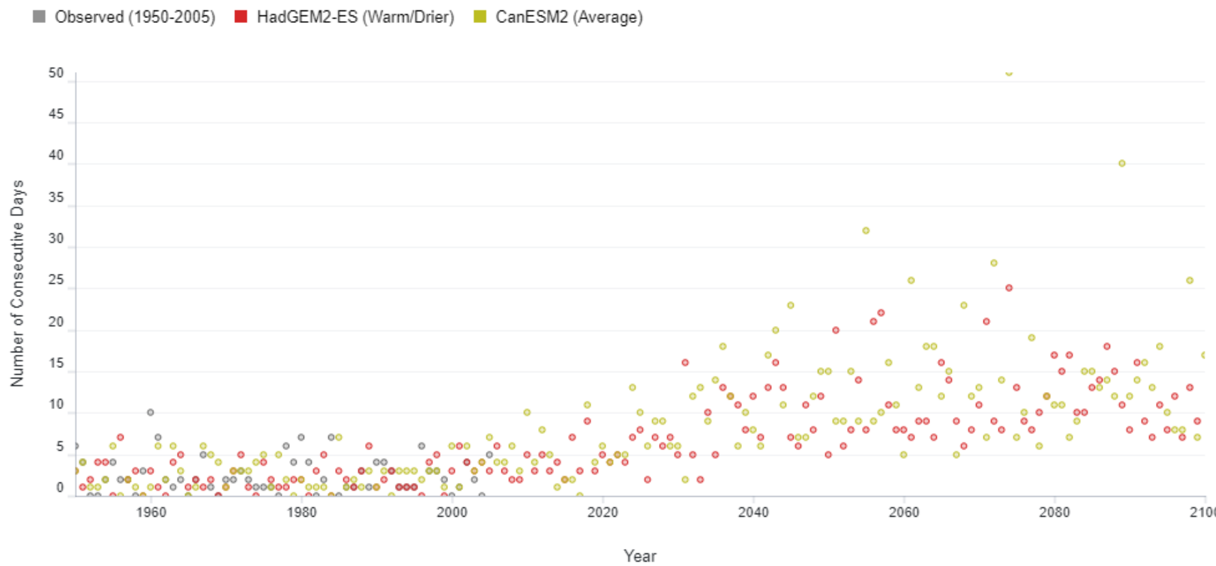

Figure 5. Longest Stretch of Consecutive Extreme Heat Days by Year in Fresno, Ca (Cal-Adapt)

In addition to extreme heat's direct impact on Fresno's climate, extreme heat also affects the city and surrounding area indirectly. Because this area is prominent in the agricultural industry, water supplies can be jeopardized by droughts, usually brought upon by prolonged extreme heat and lack of precipitation. Originating from snowmelt, agricultural water is supplied from the east by the Kings River found in the southern Sierra Nevada Mountains and northern California aqueducts. It is suspected there will be a slow decrease in reservoir inflow in the amount of 14%-23% by the middle of the century and 43% by the end of the century because of the lack of snow and accelerated snowmelt in the state, leading to a severe decrease in crop and livestock productivity (McCabe and Clark 2005).

Also, within the agricultural industry, many residents that live in Fresno, California also work outdoors contributing to crop and livestock production (National Agricultural 2014). Many of these workers are migrant agricultural field workers and construction workers and are exposed to extreme heat temperatures and experience health complications such as dehydration, sunstroke, and heat exhaustion. According to the National Farm Worker Ministry, between 2004 and 2008 in the Central Valley, the reported death toll of farmworkers that pass from extreme heat temperatures is at least 15 and the unreported is expected to be higher as many of these deaths are not reported (National Farm Worker Ministry 2017). Coupled with air pollution, the health risks of extreme heat are intensified in outdoor workers as they are exposed to particulate matter and emissions from agricultural burning, soil tilling, and operation of diesel-powered equipment (Jones et al. 2018).

Greenhouse Gas Reduction Plan

The City of Fresno started with the document The City of Fresno's Strategy for Achieving Sustainability in 2007. This plan evolved from a General Plan that analyzed the changing patterns of growth of Fresno to a Greenhouse Gas Reduction Plan. The Greenhouse Gas Reduction Plan was created by the City of Fresno in 2014. It was prepared to reduce greenhouse gas emissions through greenhouse gas emission policies and implementation measures while using population, employment, and housing data to estimate present and projected emissions. This plan has been updated in March of 2020 to analyze and note the progress of initiatives and forecast 2030 goals and emissions projections The main goals of the Greenhouse Gas Reduction Plan Update are to create city initiatives that will reduce greenhouse gas emissions. In relation to extreme heat, the Plan lists the following (City of Fresno 2020):

- Regional Urban Forestry Program
    - General Plan Policy POSS-1-g: Regional Urban Forest. Maintain and implement incrementally, through new development projects, additions to Fresno's regional urban forest to delineate corridors and the boundaries of urban areas, and to provide tree canopy for bike lanes, sidewalks, parking lots, and trails.

In terms of indirect ways to adapt to and mitigate impacts to extreme heat both at an upper management level and resident resources include (City of Fresno 2020):

- Policy D-3-c Local Streets as Urban Parkways. Develop local streets as "urban parkways", where appropriate, with landscaping and pedestrian spaces
- Policy RC-7-i PACE Financing. Develop a residential Property Assessed Clean Energy (PACE) program, if it is determined to be a feasible option, to help finance water efficiency and energy efficiency upgrades for property owners.

In addition, the Greenhouse Gas Reduction Plan mentions Environmental Justice in its top three goals as, “Ensure that climate protection measures do not cause increases in toxic or criteria pollutants that adversely impact public health or environmental justice communities” (City of Fresno 2020).

Gap Analysis

The following table exhibits if initiatives in the City of Fresno's Greenhouse Gas Reduction Plan fall within the guidelines of The Heatwave Guide for Cities, Characteristics for a Resilient City guidance document, and Equity by Design: Five Principles guidance documents. Overall, the city of Fresno met less than 50% of the objectives provided by the guidelines used for this analysis. The Greenhouse Gas Reduction Plan is lacking in many areas most prominently that of extreme heat warning and review systems and equity concerns.

Table 3. Gap Analysis of Greenhouse Gas Reduction Plan to Guidance Documents ((author, The International Federation of Red Cross and Red Crescent Societies 2019; Twigg 2009 Bensimon et al. 2016)

Guidance Document	Guideline Objectives	Addressed in Climate Action Plan?	Action Plan Recommendation from Guidance Document
The Heatwave Guide for Cities	Identification of extreme heat risk	X	Identification of a threshold indicates the moment when the heat becomes extreme enough to become dangerous to people’s health and livelihoods
	Preparation for extreme heat risks		Cities can invest in planning for extreme heat to reduce risks and prepare for effective response
	Heat health early warning systems		City emergency management departments can develop heatwave plans, with triggers for action that are clearly defined and understood. All key municipal and nongovernment actors should know exactly who does what and when as soon as a heatwave is forecast.
	Strategies to adapt to or mitigate impacts during an extreme heat event	X	Conduct public awareness campaign; Increase access to water; Plan for a sudden increase in electricity demand; Organize home outreach visits to vulnerable people
	After extreme heat event review		After-action reviews broadly focus on what happened, how it happened, what worked well and what improvements can be made for the future. This is an important process in building strong systems to reduce the future impacts of heatwaves. Insights gained through the review may also help to inform long-term

			heat-risk reduction strategies
Characteristics of a Disaster-Resilient Community a Guidance Note	Governance	X	
	Risk Assessment	X	
	Knowledge and Education	X	
	Risk Management and Vulnerability	X	
	Disaster Preparedness and Response		Organizational capacities and coordination; Early warning systems; Preparedness and contingency planning; Emergency resources and infrastructure; Emergency response and recovery; Participation, voluntarism, accountability
Equity by Design: Five Principles	Clarity		The clarity in language, goals, and measures is vital to effective equitable practices.
	Equity-mindedness		Adopt language that focuses on the actions of city government and systems, not the actions of residents they have been affected
	Equitable practice and policies		Equitable practice and policies are designed to accommodate differences in community types
	Analyzing Effectiveness		Enacting equity requires a continual process of learning, disaggregating data, and questioning assumptions about relevance and effectiveness.
	System-Wide Principle	X	

Oakland

Community Characteristics and Vulnerability

West Oakland in the 1930s and 1940s became a destination for African American migration from southern states as housing projects and opportunity became available. West Oakland became home to many residents when there was prominent housing discrimination and limited housing opportunities for racial minorities. Housing developments barred racial minorities from buying homes elsewhere in the East Bay Area. Eventually, West Oakland held the largest

African American community in Northern California. Poverty rates climbed in the area as many manufacturing industries moved out of Oakland, California. On the other end of the city, East Oakland grew quickly in the early 1900s as African Americans moved to the area post World War II. Eventually, this neighborhood also grew in diversity as it increased in population adding Hispanic, Latino, and Asian residents.

In 2018, Oakland, CA had a population of 429,000 people with a median age of 36.8 and a median household income of about $75,000 (United States Census Bureau 2019). The population grew 0.92% from 2017 and 2018 to 425,204 to 429,114. 26.5% of Oakland's residents are Latino or Hispanic and 22.7% are African American or Black, making the city's racial demographic almost 50% non-white (United States Census Bureau 2019). Median household income in Oakland grew 8.35% from $70,577 to $77,000 (United States Census Bureau 2019). In West Oakland, the median income of residents is about $40,000, well below the median income of residents. In addition to low economic status, many communities in Oakland are heavily burdened by pollution from the Port of Oakland and nearby freeways. According to CalEnviroScreen, much of the city falls into the 90 to 100 percentiles (Figure 6) (California Environmental Protection Agency 2018).

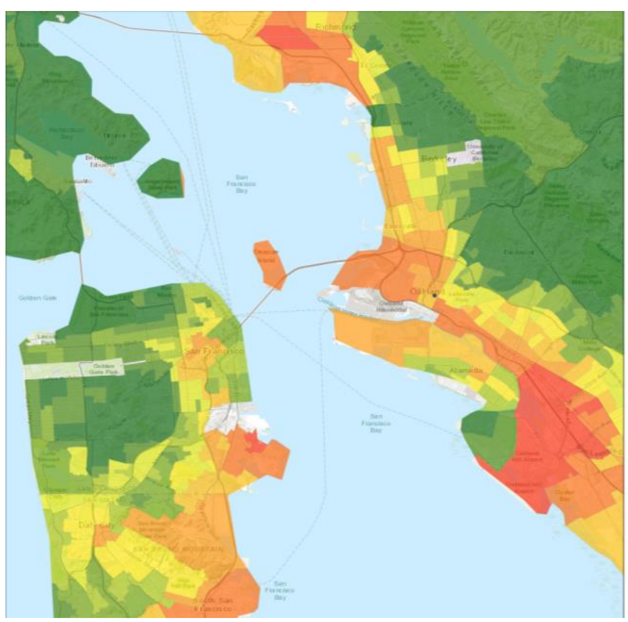

Figure 6. CalEnviroScreen: Oakland, Ca (Cal EnviroScreen)

Oakland, California is in California Climate Zone 3. In Zone 3, there is a great variation of elevation and coastal influence. In places with more coastal influence, moderate temperatures are experienced year-round with late summer fog and winter rain (Bromirski et al. 2003). In some areas of Oakland that are inland from sea cliffs and beaches, there is reduced fog cover, less wind, and an increase in summer heat. Extreme heat is expected to increase in frequency and duration. Typically, the average temperature ranges from 44°F to 75°F and is rarely below 37°F or above 85°F (University of California and California Energy Commission 2020). The threshold temperature of what constitutes extreme heat is 88.2°F (University of California and California Energy Commission 2020). The number of extreme heat days is expected to increase for the foreseeable future. Between 1971 and 2000, the 7.6 was the average number of days where the daily maximum temperature was above the maximum (University of California and California Energy Commission 2020). By the middle of the century, the above-average, over daily maximum temperature days will double. By the end of the century, the number of days may triple.

Oakland, California will be burdened by energy insecurity during extreme heat events. The number of Cooling Degree Days, a measurement used to quantify the demand for energy needed to cool buildings, is also expected to increase. The average number of Cooling Degree Days between 1961 to 1990 was 148 days per year, whereas, for the next 70 years, there will be an average of 658 days per year (Figure 7) (University of California and California Energy Commission 2020).

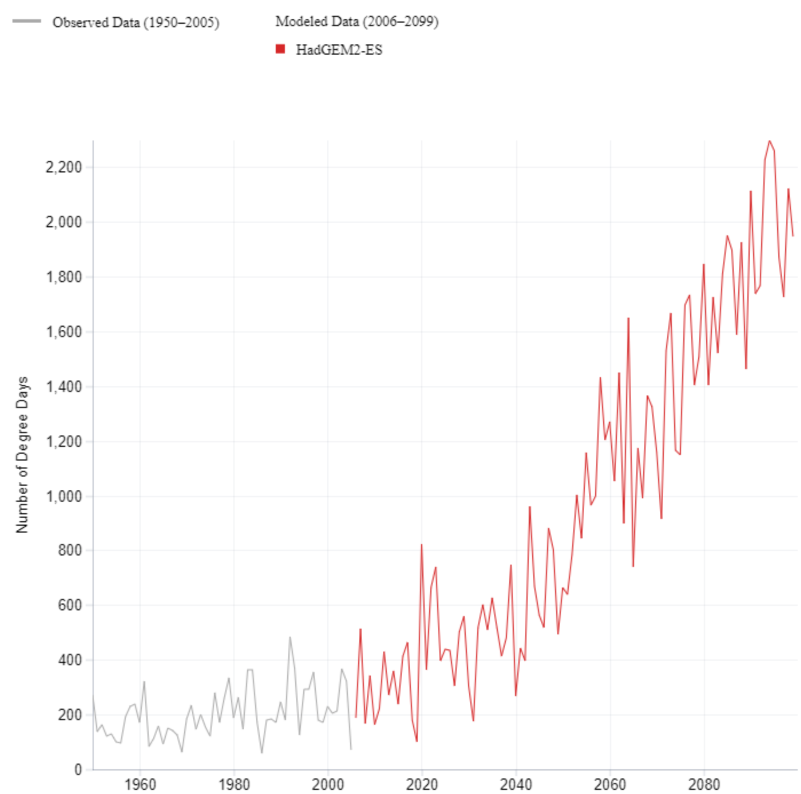

Figure 7. Cooling Degree Days in Oakland, Ca (Cal-Adapt)

Because of the traditionally low temperatures, many homes in Oakland are not likely to have air conditioning systems. The increase in the number of Cooling Degree Days will require many residents to purchase air conditioning systems. In Oakland, 10.5% of residents own air conditioning systems, and the systems are used 9% of the year (Ostro et al. 2010). The average cost of air conditioning materials and equipment is $597.00 (Ostro et al. 2010). This cost, however, does not include permitting costs, inspection cost, state and local taxes, and general contractor fees that go along with installing an air conditioning system. Because of this, many residents will require air conditioning systems in their home, however many homes in the Bay Area do not have air conditioning systems because of the traditionally low temperatures. This burden of energy insecurity is highlighted in the city of Oakland as many residents living in low income neighborhoods are unable to purchase systems and continue to pay for ongoing costs.

2020 Energy and Climate Action Plan

The City of Oakland created the Energy and Climate Action Plan which is a roadmap for the city to reach its sustainability and climate goals (December and 2012 (Updated March 2018). The plan was first adopted in 2012 by the City Council and was revised in 2017-2018. The City Council worked with social justice groups, environmental stakeholders, green business groups, and city departments to strengthen their plan and provided updated information on completed initiatives, reprioritized actions, and a recent greenhouse emission inventory. Currently, the City of Oakland is developing the 2030 Equitable Climate Action Plan (ECAP) that will also prioritize equitable actions when reducing climate emissions.

The main goals of the 2020 ECAP are to identify and prioritize city initiatives that will reduce energy consumption and greenhouse gas emissions. In direct relation to extreme heat, the ECAP lists the following Priority Actions (City of Oakland 2020):

- PA 15. Include Measure to Reduce the Urban Heat Island Effect in Planning Documents
- PA 24. Develop an Urban Forestry Master Plan
- PA 26. Update City Tree Ordinances
- PA 27. Implement Street Tree Planting Pilot

In addition, extreme heat mitigation and adaptation measures are explained in the ECAP under the chapter "Achieving a 36% GHG Reduction-the 2020 Plan" under the subheading "Adapting and Increasing Resilience to Climate Change". A strategy to achieve 2020 goals include that directly relates to extreme heat is (City of Oakland 2020):

- Action AD-8: Update planning documents and building codes to include requirements for high albedo (reflective) surfaces where possible (e.g., rooftops, pavement) to reduce the urban heat island effect and mitigate public health impacts of extreme heat events.
- Action BE-4: Offer property-based financing and associated outreach for energy efficiency and solar improvements to residential and commercial property owners in Oakland.

Growing on the strategy to minimize the urban heat island effect, the ECAP states the following objective, "Develop Oakland's urban forest throughout the city". This strategy is also meant to reduce city temperatures, mitigate negative air quality, and heat-health risks. Within this section, the following actions are included (City of Oakland 2020):

- Action TLU-45: Develop an urban forestry master plan outlining how the City will protect, develop and maintain diversified and appropriate tree plantings on City right-of-ways.
- Action TLU-46: Develop a robust urban tree inventory of all trees in proximity to sidewalks, medians, public buildings, parks and other public right-of-ways.
- Action TLU-47: Revise the City Street Trees and Shrubs Ordinance (Municipal Code 12.32) and the Protected Trees Ordinance (Municipal Code 12.36) to : include the provision of preventative maintenance and management of trees in City right-of-ways, ensure the continued health of all parks and forested land within the city, encourage tree planting on private land throughout the community, and include effective enforcement provisions.
- Action TLU-48: Implement a street tree planting pilot project with local partners utilizing advanced planting techniques.
- Action TLU-49: Develop a plan to ensure the continued health of all parks and forested land within the city and encourage tree planting on private land throughout the community.
- Action TLU-50: Convene community workshops to educate community members on proper tree maintenance.
- Action TLU-51: Collaborate with local organizations where appropriate to advance local urban forestry efforts.

Throughout the ECAP, city managers also listed strategies that can indirectly relate to the adaptation and mitigation of extreme heat. The following strategies will result in positive adaptation and mitigation strategies as well as indirect resources for residents to reduce heat-health risk (City of Oakland 2020):

- PA 1. Launch and Develop a Funding Plan for the Downtown Shuttle
- PA 2. Advance Bus Rapid Transit in Oakland
- PA 5. Launch a Residential Green Retrofit Program
- PA 10. Expand Outreach on Energy and Climate Issues through Partnerships with Local Organizations
- PA 30. Seek Resources to Support Energy Programs
- PA 34. Launch the Weatherization and Energy Retrofit Loan Program
- PA 35. Create a Renter-Occupied Residential Energy Retrofit Program
- PA 53. Promote the Development of Oakland's Urban Forest

In terms of the direct and indirect impacts of extreme heat and its relationship to equity, the ECAP incorporates this in the following initiatives (City of Oakland 2020):

- PA 8. Offer Property-Based Energy Financing
- PA 10. Encourage Participation in Local Energy Efficiency Programs
- PA 36: Adopt and Implement a Residential Energy Conservation Ordinance
- TLU-6: Identify and Adopt Priority Development Areas
- Action BE-25: Adopt an ordinance requiring cost-effective residential energy-and water-related improvements at time of sale, or under other appropriate conditions with consideration of affordability and equity.

Gap Analysis

The following table exhibits if initiatives in the City of Oakland's 2020 Energy and Climate Action Plan fall within the guidelines of The Heatwave Guide for Cities, Characteristics for a Resilient City guidance document, and Equity by Design: Five Principles guidance document. Overall, the city of Oakland met over 70% of the objectives provided by the guidelines used for this analysis. The Energy and Climate Action Plan is lacking in areas of extreme heat review strategies and overall equity inclusivity.

Table 4. Gap Analysis of 2020 Energy and Climate Action Plan to Guidance Documents (author, The International Federation of Red Cross and Red Crescent Societies 2019; Twigg 2009 Bensimon et al. 2016)

Guidance Document	Guideline Objectives	Addressed in Climate Action Plan?	Action Plan Recommendation from Guidance Document
The Heatwave Guide for Cities	Identification of extreme heat risk	X	
	Preparation for extreme heat risks	X	
	Heat health early warning systems		City emergency management departments can develop heatwave plans, with triggers for action that are clearly defined and understood. All key municipal and nongovernment actors should know exactly who does what and when as soon as a heatwave is forecast.
	Strategies to adapt to or mitigate impacts during an extreme heat event	X	
	After extreme heat event review		After-action reviews broadly focus on what happened, how it happened, what worked well and what improvements can be made for the future. This is an important process in building strong systems to reduce the future impacts of heatwaves. Insights gained through the review may also help to inform long-term heat-risk reduction strategies
Characteristics of a Disaster-Resilient Community a Guidance Note	Governance	X	
	Risk Assessment	X	
	Knowledge and Education	X	
	Risk Management and Vulnerability	X	
	Disaster Preparedness and Response	X	
Equity by Design: Five Principles	Clarity	X	
	Equity-mindedness		Adopt language that focuses on the actions of city government and systems, not the actions of residents they have been affected

	Equitable practice and policies	X	
	Analyzing Effectiveness	X	
	System-Wide Principle		There is clear, compelling, and consistent messaging about the urgency of reducing disparities through equitable policies and practices

Los Angeles

Community Characteristics

In 2018, Los Angeles, CA had a population of 3.99 million people with a median age of 35.8 and a median household income of about $62,000 (United States Census Bureau 2019). The population decreased by 0.23% between 2017 and 2018 from 4 million people to 3.99 million people (United States Census Bureau 2019). 49% of Los Angeles's residents are Latino or Hispanic and 11.9% are Asian, leaving the city's racial demographic almost over 60% non-white. Median household income in Los Angeles grew 3.8% from about $60,000 to about $62,500 (United States Census Bureau 2019). Los Angeles experiences high air pollution levels given their geographical location and high population density. Based on the 2010 US Census data, Los Angeles had a population density of over 7,500 people per square mile (United States Census Bureau 2019). According to CalEnviroScreen, much of the city falls into the 90 to 100 percentiles (Figure 8) (California Environmental Protection Agency 2018).

The community of Boyle Heights in Los Angeles, Ca, most of the population works in the manufacturing and service industry which provides low wages making homeownership difficult to obtain. 77% of residents in Boyle Heights are renters experiencing high rent rates that account for over 50% of the household's income which is around $33,000 (US Census Bureau, American FactFinder 2017). In this community, nearly 40% of residents do not have access to healthcare, limiting resources to treat illness brought upon by pollution and other environmental conditions (United States Census Bureau 2019).

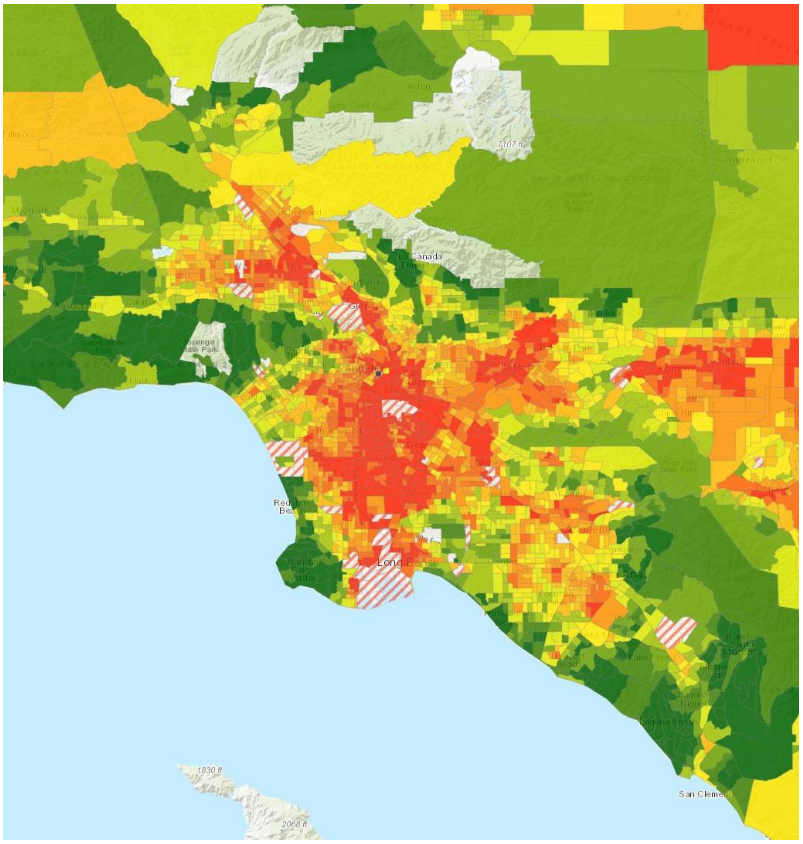

Figure 8. CalEnviroScreen: Los Angeles, Ca (CalEnviroScreen)

In Los Angeles California, extreme heat is expected to increase in frequency and duration, especially in urban areas as the urban heat island effect greatly increases local temperatures. Typically, the average temperature ranges from 48°F to 85°F and is rarely below 42°F or above 93°F (University of California and California Energy Commission 2020). The threshold temperature of what constitutes extreme heat is 106°F (University of California and California Energy Commission 2020). The frequency of extreme heat days is expected to increase. Between 1961 and 1990, the number of extreme heat days per year was 4 days. From 2050-2099, the number of extreme heat days per year will be 16 days, while the number of days is 7 within the next decade (University of California and California Energy Commission 2020).

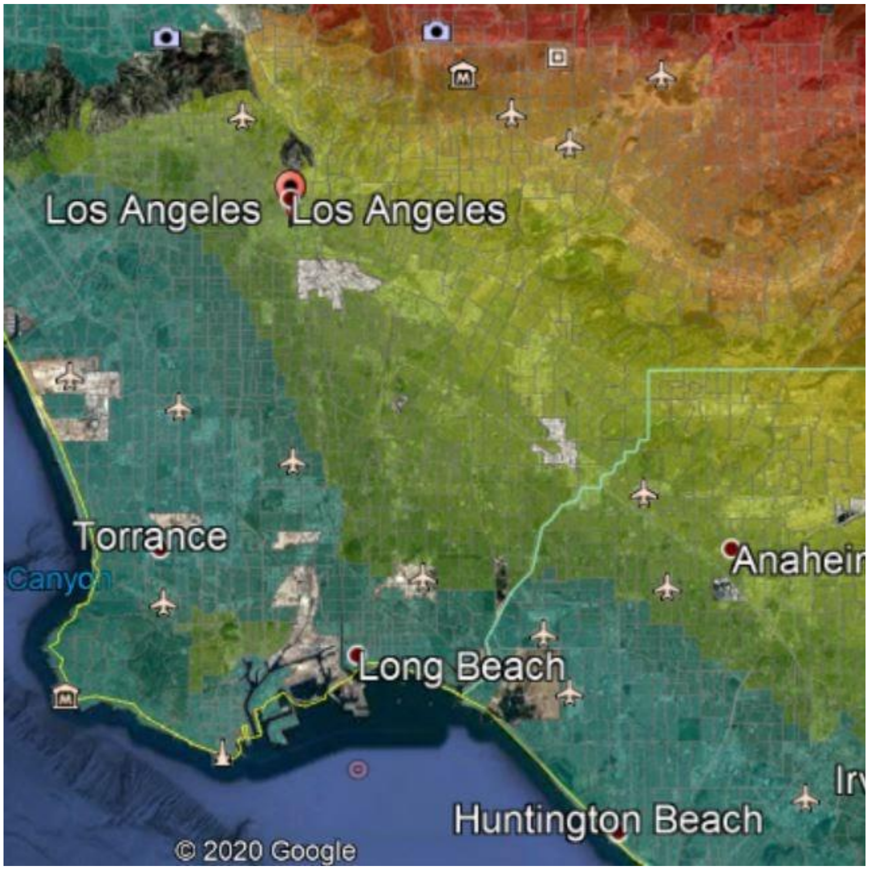

Figure 9. Urban Heat Island: Los Angeles, Ca (Google Earth, Urban Heat Island Index)

Large urban areas in Los Angeles, urban heat islands blend to create an urban heat archipelago where the increase in average temperature is spread over a larger area. This can result in up to a 19° F at the eastern end of the area (Taha 2017). The section in red shows an area that absorbs and retains more heat. The section in green shows areas that do not absorb or retain much heat. Figure 9 also shows warmer temperatures are more likely to occur inland rather than by the coast. A cause of the urban heat island effect in Los Angeles is also attributed to the increase in CO2 emissions. As shown in Figure 9 the area in red marks a zone called the "nonattainment" zone. The "nonattainment" zone is an area where the local air quality does not qualify as good air quality as defined by the National Ambient Air Quality Standards (NAAQS). Whereas, the area in green marks a zone called the "attainment" zone. In this zone, the air quality meets the NAAQS standard. The city of Los Angeles is in the area marked in red, the "nonattainment zone". The city's contribution to greenhouse gas emissions, and geographical location providing a pathway for wind from the Pacific Ocean, increases the severity of the urban heat island effect on the western side.

L.A.'s Green New Deal

The City of Los Angeles created L.A.'s Green New Deal, a Sustainable City pLAn, which is a document to highlight Los Angeles' sustainability and climate goals. The plan is updated every four years to provide information on changing challenges facing the community, economy, and environment. The plan also renews commitments as well as arguments, expands, and elaborates on their accelerated targets and goals. The following are the key principles presented in the Green New Deal (City of Los Angeles 2020):

- First, a commitment to the Paris Climate Agreement and to act urgently with a scientifically driven strategy for achieving a zero-carbon grid, zero carbon transportation, zero carbon buildings, zero waste, and zero wasted water.
- Second, a responsibility to deliver environmental justice and equity through an inclusive economy, producing results at the community level, guided by communities themselves.
- Third, a duty to ensure that every Angeleno can join the green economy, creating pipelines to good paying, green jobs and a just transition in a changing work environment.
- Fourth, a resolve to demonstrate the art of the possible and lead the way, walking the walk and using the City's resources - our people and our budget - to drive change.

In relation to extreme heat, L.A.'s Green New Deal lists the following adaptation and mitigation measures in the following categories (City of Los Angeles 2020):

- Urban Ecosystem and Resilience
    - Target: Reduce urban/rural temperature differential by at least 1.7 degrees by 2025; and 3 degrees by 2035
        - All new roofs must be cool roofs by 2020; and install 13,000 additional cool roofs by 2021

        - Pilot 6 cool neighborhoods in vulnerable communities by 2021; and 10 by 2025
        - Install cool pavement material on 250 lane miles of City streets, prioritizing neighborhoods with the most severe heat island effect
        - Incorporate additional cooling features such as innovative shade design, water features, and cooling centers at parks
    - Target: Increase tree canopy in areas of greatest need by at least 50% by 2028 to grow a more equitable urban forest that provides cooling, public health, habitat, energy savings, and other benefits
        - Plant and maintain at least 90,000 trees citywide
        - Complete citywide tree inventory by 2021; and an Urban Forest Management Plan by 2025

In terms of the direct and indirect impacts of extreme heat and its relationship to equity, the L.A.'s Green New Deal incorporates this in the following initiatives (City of Los Angeles 2020):

- Environmental Justice
    - Target: Improve the raw scores of CalEnviroScreen indicators of L.A. communities in the top 10% by an average of 25% by 2025; and 50% by 2035
        - Partner with LAUSD to formalize an agreement to establish joint use parks in schools
        - Upgrade cooling centers to better meet the needs of elderly and persons with disabilities
        - Expand communications on types of cooling resources and available cooling spaces, including through NotifyLA for homeless populations, to increase usage and deployment
        - Targeted outreach to renters and affordable housing customers for energy efficiency rebate opportunities
        - Provide discounted energy benchmarking for affordable housing and non-profits with trainees from local colleges

- Identify opportunities to implement cool corridors and other interventions to improve pedestrian comfort on routes to high-volume transit stops and cooling spaces
- Implement a Street Furniture program that reduces heat exposure, provides cool transit stops, and improves access to restrooms in high transit use areas
- Identify low canopy corridors and prioritize planting trees in those areas

Gap Analysis

The following table exhibits if initiatives in the City of Los Angeles's Green New Deal fall within the guidelines of The Heatwave Guide for Cities, Characteristics for a Resilient City guidance document, and Equity by Design: Five Principles guidance document. Overall, the city of Los Angeles met 100% of the objectives provided by the guidelines used for this analysis and provided in-depth and inclusive initiatives to adapt to and mitigate the impacts of extreme heat while being inclusive to all community types.

Table 5. Gap Analysis of L.A.'s Green New Deal to Guidance Documents ((author, The International Federation of Red Cross and Red Crescent Societies 2019; Twigg 2009 Bensimon et al. 2016)

Guidance Document	**Guideline Objectives**	**Addressed in Climate Action Plan?**	**Action Plan Recommendation from Guidance Document**
The Heatwave Guide for Cities	Identification of extreme heat risk	X	
	Preparation for extreme heat risks	X	
	Heat health early warning systems	X	
	Strategies to adapt to or mitigate impacts during an extreme heat event	X	
	After extreme heat event review	X	

Characteristics of a Disaster-Resilient Community a Guidance Note	Governance	X	
	Risk Assessment	X	
	Knowledge and Education	X	
	Risk Management and Vulnerability	X	
	Disaster Preparedness and Response	X	
Equity by Design: Five Principles	Clarity	X	
	Equity-mindedness	X	
	Equitable practice and policies	X	
	Analyzing Effectiveness	X	
	System Wide Principle	X	

Comparative Analysis

Comparing Community Characteristics and Vulnerability

Table 6. Comparison of Extreme Heat Duration and Frequency (author, Cal-Adapt)

	Average Number of Cooling Degree Days (2070-2099)	Number of Extreme Heat Days (2070-2090)	Number of 4 Day Heat Waves by Year (2070-2099)	Maximum Duration of Extreme Heat Days by Year (2070-2099)
Fresno	2985	36	2.4	12.8
Oakland	588	11	0.6	3.7
Los Angeles	1835	15	1.3	4.8

As shown in Table 6, each city is expected to experience different impacts of extreme heat in terms of duration, frequency, and the number of cooling degree days. This is attributed to geographical location, the urban heat island effect, and regional weather patterns (Arbuthnott et al. 2016). Out of the three case studies, Fresno, Ca is expected to have the biggest increase in duration and frequency of extreme heat events along with naturally high seasonal temperatures. On the other hand, the city of Oakland, will have the least amount of heat waves and number of heat wave events. Although the values for each city vary greatly, it is important to note that because of geographical characteristics, the increase in extreme heat events, in both frequency and duration, will affect each city in different magnitudes.

The three cities chosen for this analysis, Oakland, Fresno, and Los Angeles, each consist of environmental justice communities and populations that are vulnerable to the impacts of extreme heat. Using climate modeling tools, each city will experience more frequent and longer extreme heat days and heat waves throughout the year. In terms of impacts, the most common among the cities is public health. Although the residents are exposed differently, the likelihood of hospitalizations and heat health risk is apparent. One example of a difference in public health impact is that the residents of Fresno, California are more likely to be outdoor workers and are exposed to particulate matter from equipment powered by diesel. On the other hand, the residents of Oakland, California and Los Angeles, California are impacted by greenhouse gas pollution given densely populated living areas resulting in an increase of vulnerability.

Comparing Objectives of Guidance Documents

Table 7. Comparison of Guidance Documents to Case Study Cities (author)

Guidance Documents	Guideline Objectives	Fresno	Oakland	Los Angeles
The Heatwave Guide for Cities	Identification of extreme heat risk	X	X	X
	Preparation for extreme heat risks		X	X
	Heat health early warning systems		X	X

	Strategies to adapt to or mitigate impacts during an extreme heat event	X		X
	After extreme heat event review		X	X
Characteristics of a Disaster-Resilient Community a Guidance Note	Governance	X		X
	Risk Assessment	X	X	X
	Knowledge and Education	X	X	X
	Risk Management and Vulnerability	X	X	X
	Disaster Preparedness and Response		X	X
Equity By Design: Five Principles	Clarity		X	X
	Equity-mindedness			X
	Equitable practice and policies		X	X
	Analyzing Effectiveness		X	X
	System Wide Principle	X		X

Listed here is a table showcasing the gaps within the climate action plans of each city showcased in the case studies. As shown here, Fresno, Ca met less than 50% of the objectives stated in the guidelines used for analysis. On the other hand, the city of Los Angeles met every objective. It is important to mention that climate action plans can be tackled on different levels of government as plans are created based on resources. For example, the county of Fresno released a Climate Wise Plan which encompassed the Fresno Metropolitan Area. But, even within this document, limited initiatives were mentioned to address extreme heat resiliency and equitable actions. Overall, it is apparent that there is a range of development among climate action plans of cities with environmental justice communities.

Conclusion and Recommendations

The overall objective of this project was to identify gaps within local government Climate Action Plans in cities that contain environmental justice communities. By identifying the gaps, recommendations can be made to strengthen local government Climate Action Plans by including inclusive and equitable measures to adapt to and mitigate the impacts of extreme heat. To reach this overall objective, the main research questions for this project were: Do existing local government Climate Action Plans for cities with environmental justice communities address appropriate measures to adapt to and mitigate the impacts of extreme heat? And What management efforts can be made to ensure environmental justice communities are not disproportionately impacted by extreme heat? To further understand how extreme heat affects cities and how urban resilience can be used to mitigate and adapt to impacts, I also aimed to understand extreme heat and its impacts, analyze local government Climate Action Plans of three cities in California with environmental justice communities, identify city community characteristics and the vulnerability to extreme heat, assess gaps within local government Climate Action Plans of cities with environmental justice communities to urban resilience, extreme heat, and equity guidelines, and ultimately develop management strategies to adapt to and mitigate the impacts of extreme heat.

Conclusion

My research analyzed local government Climate Action Plans of three cities in California, Fresno, Oakland, and Los Angeles, each with environmental justice communities, to determine if appropriate adaptation and mitigation measures for extreme heat are addressed. Climate change projections suggest extreme heat events will be more frequent over the next few decades and extreme heat has both negative environmental and social impacts as it affects energy security, public health by increasing the risk of heat related illnesses, and the intensification of the urban heat island effect. The impacts from extreme heat will also disproportionately affect communities of low economic status. Therefore, adequate local government Climate Action Plans are imperative. However, many cities, even with designated environmental justice communities, are lacking strength in their plans to adapt to and mitigate the impact of extreme heat, and most importantly, provide concrete measures to prevent disproportionately impacting vulnerable and disadvantaged members of the community.

Recommendations

Given the gaps identified in local government Climate Action Plans, I have created recommendations to strengthen the areas where the objectives of the Heatwave Guide for Cities are lacking in the plans and intertwined the Equity Principles to create examples of initiatives that provide an inclusive and equitable approach to adapting to or mitigating the impacts of extreme heat.

Gap 1: Identification of extreme heat risk

One of the objectives given the Heatwave Guide for Cities is identification of extreme heat risk. In order to understand heat risk, cities can identify a threshold of what constitutes extreme heat. It is beyond this temperature that heat can become dangerous to people's lives, health, and livelihood. Identification of heat risk at an individual and community level determines what the existing levels of risks are and to increase the understanding of vulnerabilities.

Recommendation: Create methods for a vulnerability assessment

In order to fill the gap of identifying extreme heat risk, a recommendation is to create methods for vulnerability assessment. Within this assessment, vulnerable communities can be identified and prioritized meeting the equity principles of equity mindedness, analyzing effectiveness, and equitable practices and policies. According to Canada's Heat Alert and Response Systems to Protect Health: Best Practices Guidebook, there are six steps that can be taken to conducting an extreme heat and health vulnerability assessment (Water, Air and Climate Change Bureau Healthy Environments et al. 2012). These steps include initiating the assessment by developing a workplan and organizing stakeholders. The next step is to describe current vulnerability by characterizing heat exposure, community vulnerability, individual vulnerability, and the evaluation of effectiveness of existing programs. Following this, it is recommended to assess future risks by describing expected trends that may influence heat-related health outcomes and describe possible additional health outcomes. The next step is to identify adaptation options by assessing barriers to adaptation and prioritization of options. Following this is to examine measures in other sectors. And finally, develop performance protocols for adaptation measures and monitoring the burden of vulnerable communities.

Gap 2: Heat health early warning system

A heat health early warning system involves the forecasting of a heatwave event, predicting what the possible health outcomes would be, when to trigger effective and timely response plans that target the most vulnerable populations. In addition to this, an early warning system will also provide notifications of heatwave events. It is through the early warning systems that mortality and morbidity can be reduced or prevented (Ebi and Schmier 2005).

Recommendation: Develop an alert protocol that will identify an alert trigger and call alerts

In order to fill the gap of having a heat health early warning system in local government Climate Action Plans, the plans need core elements. The core elements of systems include a heat health threshold which triggers a warning, communication of that warning, action to reduce impacts, and an evaluation of the actions taken (The International Federation of Red Cross and Red Crescent Societies 2019). Within this development of triggers and resulting call alerts, environmental justice communities can be identified and prioritized meeting the equity principles of equity mindedness, analyzing effectiveness, and equitable practices and policies given their location (i.e. located in urban areas affected by the intensification of the urban heat island effect) or vulnerability (i.e. larger population of older residents)..

Alert triggers can be identified through different metrics. The identification of triggers is meant to protect human health as it combines information regarding community vulnerability and regional weather and climate that can result in heat related health risks. An alert trigger is community specific as it is based on different meteorological parameters such as temperature and humidity. Within these parameters, an alert trigger is determined by the frequency, duration, and magnitude of extreme heat events, extreme humidity events, anthropogenic conditions such as negative air quality, and other factors such as infrastructure insecurity and damage (Water, Air and Climate Change Bureau Healthy Environments et al. 2012). The issuance of alerts is based on triggers, a combination of triggers, or the intensity of triggers. Also, within the alerts, many agencies are responsible for communicating the information as it fits their responsibility. For example, the energy sector will communicate information of possible power outages or heat fluxes.

Gap 3: Preparation for heat season and heat waves

One of the objectives of the Heatwave Guide for Cities is preparing for the heat season and heat wave. When preparing for the heat season, cities can invest in adaptation and mitigation measures to prepare for an effective response given the city's vulnerability to extreme heat (The International Federation of Red Cross and Red Crescent Societies 2019). This includes seasonal planning, where different strategies are implemented throughout the year, and sector planning, where different sectors are prepared for heat waves (i.e. emergency management teams prepare strategies for effective response plans). When preparing for a heatwave, strategies can be planned closer to the days of the extreme heat event. It is at this time, cities can implement communication warnings, address risk perception, and prepare city sectors. Within this preparation, environmental justice communities can be identified and prioritized meeting the equity principles of equity mindedness and clarity.

Recommendation: Review and improve access to and use of air conditioning and other indoor cooling strategies

In order to fill the gap in local government Climate Action Plans of the lack of preparation for the heat season and imminent heatwave, the guidance document Preparing California for Extreme Heat: Guidance and Recommendations recommends that agencies should review and improve access to and the use of air conditioning and other cooling strategies. It is through this recommendation that the extreme heat impact of energy insecurity in environmental justice communities can be prevented. Within this recommendation, agencies can improve access to air conditioning, address obstacles that prevent residents from using air conditioning, improve communication of energy insecurity and the importance of keeping cool during extreme heat events, identifying alternatives to air conditioning, and developing indoor air temperature guidelines as age groups require different indoor air temperature because of health vulnerabilities (California Environmental Protection Agency and California Department of Public Health 2013).

In addition to the review and improving access to cooling strategies, cities can prepare for the heat season and heat waves by protecting energy systems and expanding energy assurance (California Environmental Protection Agency and California Department of Public Health 2013). Agencies can achieve this by working with utilities and fuel providers to ensure cooling centuries and other essential services in vulnerable areas are protected. As well as expanding the California Local Energy Assurance Planning. This will provide additional guidance to local jurisdictions by introducing strategies for a clean, reliable, and cost-effective energy sector.

Gap 4: Reducing heat risk

One of the objectives of the Heatwave Guide for Cities is reducing heat risk. When planning to reduce heat risk, cities can invest in urban planning tools and strategies to prepare for an effective response given the city's vulnerability to extreme heat (The International Federation of Red Cross and Red Crescent Societies 2019). By reducing heat risk through urban planning, the strategies will provide a long-term solution to the adaptation and mitigation of extreme heat. The greatest impact across agencies can be seen through the adoption of urban planning strategies (Hughes 2015). Within this reduction of heat risk, environmental justice communities can be identified and prioritized meeting the equity principles of equity practices and policies.

Recommendation: Implement cooling strategies in urban planning to reduce the urban heat island effect through changes in regulations, building codes, and design elements

In order to fill the gap in local government Climate Action Plans of urban resilience strategies, the guidance document Preparing California for Extreme Heat: Guidance and Recommendations recommends that agencies review and incorporate changes to state and local regulations, codes and industry practices for buildings as well as land use and design elements. This will be used to identify areas to accelerate the inclusion of cooling strategies for both indoor and outdoor environments (California Environmental Protection Agency and California Department of Public

Health 2013). In many of the local government Climate Action Plans, the implementation of urban forestry to reduce the urban heat island effect is common. However, with the changes of regulations and codes, multiple strategies can be put in place in many sectors. Changes include updates to Title 24 to include measures that will mitigate future health risks of extreme heat and measures that will cool the interior of the building as well as contribute to the reduction of the urban heat island effect. In addition, urban planning strategies should also be included in indoor air quality standards and codes, as well as incorporated into land use planning in building dense areas.

Gap 5: Knowledge and Education

One of the thematic areas of the Characteristics of a Disaster-Resilient Community: A Guidance Note is knowledge and education. In this, thematic area there are the following components of resilience: public awareness, knowledge and skills; information management and sharing; education and training; cultures, attitudes, motivation; learning and research (Twigg 2009). Overall, this thematic area focuses on the communication and education of all community members. Communication and conveyance of information from local governments instills trust in residents and this trust can evolve into more community involvement (Schrock et al. 2015, ERS 2017). As the relationship continues to grow, engagement in urban resilience and climate change impacts will result in community preparedness as well (Yuen et al. 2017).

Recommendation: Development of a communication plan focused on vulnerable communities

In order to fill the gap of knowledge and education, a recommendation is to create a communication plan. A communication plan is a mix of strategies that can disperse information to many residents to inform the community of extreme heat impacts. Within this strategy, vulnerable communities can be identified and prioritized meeting the equity principles of clarity, equity mindedness, and. According to Canada's Heat Alert and Response Systems to Protect Health: Best Practices Guidebook, there are multiple steps that can be taken to advance the city communication plan (Water, Air and Climate Change Bureau Healthy Environments et al. 2012). Examples of targeted communication strategies include disseminating heat information through health care providers, create strategies to reach vulnerable communities during extreme heat events, provide interactive tools that cater to different age groups and education levels, use media to distribute information, advertise cooling centers, educate employers and employees who works outdoors or heat risk workplaces, and create symbols and graphics that can be understood through many languages.

Recommendations for Future Research

To further the analysis of the adequacy of local government Climate Action Plans to adapt to and mitigate the impacts of extreme heat, I recommend the following additional research. The first is research and development of a comprehensive framework solely for extreme heat resilience in environmental justice communities in particular, and other populations in general. A second research recommendation is the identification of heat adaptation strategies that have other health benefits; for example, an evaluation of strategies that not only lessen the direct impacts of extreme heat, but also aid in maintaining air quality, to avoid the formation of smog and related public health impacts. Finally, I recommend research and evaluation of the effectiveness of early heat warning systems and communication plans.

Literature Cited

Addington, R. N., S. J. Hudson, J. K. Hiers, M. D. Hurteau, T. F. Hutcherson, G. Matusick, and J. M. Parker. 2015. Relationships among wildfire, prescribed fire, and drought in a fire-prone landscape in the south-eastern United States. International Journal of Wildland Fire 24:778-783.

Ahdoot, S., and S. E. Pacheco. 2015. Global climate change and children's health. Pediatrics 136:e1-e17.

Alexander, M. A., D. J. Vimont, P. Chang, and J. D. Scott. 2010. The impact of extratropical atmospheric variability on ENSO: Testing the seasonal footprinting mechanism using coupled model experiments. Journal of Climate 23:2885-2901.

Alkon, A. H., and J. Agyeman. 2011. Cultivating food justice: Race, class, and sustainability. :408.

Anderson, G. B., K. W. Oleson, B. Jones, and R. D. Peng. 2016. Projected trends in high-mortality heatwaves under different scenarios of climate, population, and adaptation in 82 US communities. Climatic Change 146:455-470.

Barreca, A., K. Clay, O. Deschenes, M. Greenstone, and J. S. Shapiro. 2016. Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. Journal of Political Economy 124:105-159.

Basu, R., L. Gavin, D. Pearson, K. Ebisu, and B. Malig. 2018. Examining the association between apparent temperature and mental health-related emergency room visits in California. American Journal of Epidemiology 187:726-735.

Bensimon, E. M., A. C. Dowd, and K. Witham. 2016. Five principles for enacting equity by design. Diversity and Democracy 19:1-8.

Berisha, V., D. Hondula, M. Roach, J. R. White, B. McKinney, D. Bentz, A. Mohamed, J. Uebelherr, and K. Goodin. 2017. Assessing adaptation strategies for extreme heat: A public health evaluation of cooling centers in Maricopa County, Arizona. Weather, Climate, and Society 9:71-80.

Bobb, J. F., Z. Obermeyer, Y. Wang, and F. Dominici. 2014. Cause-specific risk of hospital admission related to extreme heat in older adults. JAMA 312:2659-2667.

Bobb, J. F., R. D. Peng, M. L. Bell, and F. Dominici. 2014. Heat-related mortality and adaptation to heat in the United States. Environmental health perspectives 122:811-816.

Bohi, D. R., and M. A. Toman. 2012. The economics of energy security. Springer Science &

Business Media, .

Borden, K. A., and S. L. Cutter. 2008. Spatial patterns of natural hazards mortality in the United States. International journal of health geographics 7:64.

Bounoua, L., P. Zhang, G. Mostovoy, K. Thome, J. Masek, M. Imhoff, M. Shepherd, D. Quattrochi, J. Santanello, J. Silva, R. Wolfe, and A. M. Toure. 2015. Impact of urbanization on US surface climate. Environmental Research Letters 10:084010.

Brown, A., A. Dayal, and C. Rumbaitis Del Rio. 2012. From practice to theory: Emerging lessons from asia for building urban climate change resilience. Environment and Urbanization 24:531-556.

Brulle, R. J., and D. N. Pellow. 2006. Environmental Justice: Human Health and Environmental Inequalities. Annual review of public health 27:103-124.

Bryant, B., and P. Mohai. 2019. Race and the incidence of environmental hazards: A time for discourse. Routledge, .

Bulkeley, H., G. A. S. Edwards, and S. Fuller. 2014. Contesting climate justice in the city: Examining politics and practice in urban climate change experiments. Global Environmental Change-Human and Policy Dimensions 25:31-40.

Bullard, R. D. 1994. The legacy of American apartheid and environmental racism. St. John's Journal of Legal Commentary 9:445.

Burillo, D., M. V. Chester, S. Pincetl, and E. Fournier. 2019. Electricity infrastructure vulnerabilities due to long-term growth and extreme heat from climate change in Los Angeles County. Energy Policy 128:943-953.

Cai, W., M. Lengaigne, S. Borlace, M. Collins, T. Cowan, M. J. McPhaden, A. Timmermann, S. Power, J. Brown, C. Menkes, A. Ngari, E. M. Vincent, and M. J. Widlansky. 2012. More extreme swings of the South Pacific convergence zone due to greenhouse warming. Nature 488:365-369.

CalEPA. 2020. Environmental justice task force. :.

California Environmental Protection Agency. 2018. CalEnviroScreen. :.

Cayan, D. R., P. D. Bromirski, K. Hayhoe, M. Tyree, M. D. Dettinger, and R. E. Flick. 2008. Climate change projections of sea level extremes along the California coast. Climatic Change 87:57-73.

Centers for Disease Control and Prevention. 2019. Climate change and extreme heat: What you can do to prepare. Climate Change and Extreme Heat: What You Can Do to Prepare :.

D'Amato, G. 2002. Environmental urban factors (air pollution and allergens) and the rising trends in allergic respiratory diseases. Allergy 57 Suppl 72:30-33.

Diem, J. E., C. E. Stauber, and R. Rothenberg. 2017. Heat in the southeastern United States: Characteristics, trends, and potential health impact. PLOS ONE 12:e0177937.

Economics of Climate Adaptation, Working Group. 2009. Shaping climate-resilient development: A framework for decision-making. ClimateWorks Foundation, Global Environment Facility, European Commission, McKinsey & Company, The Rockefeller Foundation, Standard Chartered Bank and Swiss Re. Zurich, Switzerland.

Eiser, J. R., A. Bostrom, I. Burton, D. M. Johnston, J. McClure, D. Paton, J. van der Pligt, and M. P. White. 2012. Risk interpretation and action: A conceptual framework for responses to natural hazards. International Journal of Disaster Risk Reduction 1:5-16.

Europea, C. 2000. Towards a European strategy for the security of energy supply. :.

Fankhauser, S. 2017. Adaptation to climate change. Annual Review of Resource Economics 9:209-230.

Friel, S., H. Berry, H. Dinh, L. O'Brien, and H. L. Walls. 2014. The impact of drought on the association between food security and mental health in a nationally representative Australian sample. BMC Public Health 14:1102.

Gamble, J. L., B. J. Hurley, P. A. Schultz, W. S. Jaglom, N. Krishnan, and M. Harris. 2013. 3553435; Climate change and older Americans: State of the science. Environmental health perspectives 121:15-22.

General Accounting Office. 1983. Siting of hazardous waste landfills and their correlation with racial and economic status of surrounding communities. General Accounting Office. Washington, D.C.

Gingerich, S. B., V. Keener, and M. L. Finucane. 2015. Climate trends and projections for guam. East-West Center and USGS. Honolulu, HI.

Gronlund, C. J., A. Zanobetti, G. A. Wellenius, J. D. Schwartz, and M. S. O'Neill. 2016. Vulnerability to renal, heat and respiratory hospitalizations during extreme heat among U.S. elderly. Climatic Change 136:631-645.

Habeeb, D., J. Vargo, and B. Stone. 2015. Rising heat wave trends in large US cities. Natural Hazards 76:1651-1665.

Hampson, A., T. Bourgeois, G. Dillingham, and I. Panzarella. 2013. Combined heat and power: Enabling resilient energy infrastructure for critical facilities. ICF International.

Washington, DC.

Hernández-Delgado, E. A. 2015. The emerging threats of climate change on tropical coastal ecosystem services, public health, local economies and livelihood sustainability of small islands: Cumulative impacts and synergies. Marine pollution bulletin 101:5-28.

Horton, D. E., C. B. Skinner, D. Singh, and N. S. Diffenbaugh. 2014. Occurrence and persistence of future atmospheric stagnation events. Nature Climate Change 4:698-703.

Houghton, R. A. 2008. Carbon flux to the atmosphere from land-use changes 1850-2005. in TRENDS: A compendium of data on global change. :.

Huber, V., D. Ibarreta, and K. Frieler. 2017. Cold- and heat-related mortality: A cautionary note on current damage functions with net benefits from climate change. Climatic Change 142:407-418.

IEA. 2016. Decoupling of global emissions and economic growth confirmed. :.

Indian Network for Climate Change Assessment, (INCCA). 2010. Climate change and india: A 4x4 assessment. A sectoral and regional analysis for 2030s. Ministry of Environment, Forest and Climate Change. New Delhi, India.

Institute of Medicine (U.S.) Committee on Environmental Justice. 1999. Toward environmental justice : Research, education, and health policy needs. .

IPCC. 2014. Climate change 2014: Synthesis report. contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change. Intergovernmental Panel on Climate Change (IPCC). Geneva, Switzerland.

Isaksen, T. B., G. Yost Michael, K. Hom Elizabeth, Y. Ren, H. Lyons, and A. Fenske Richard. 2015. Increased hospital admissions associated with extreme-heat exposure in King County, Washington, 1990–2010. Reviews on environmental health 30:51-64.

Katz, R. W. 2010. Statistics of extremes in climate change. Climatic Change 100:71-76.

Kenney, W. L., D. H. Craighead, and L. M. Alexander. 2014. Heat waves, aging, and human cardiovascular health. Medicine & Science in Sports & Exercise 46:1891-1899.

Kilbourne, E. M. 1999. The spectrum of illness during heat waves. Am J Prev Med 16:359-360.

Kingsley, S. L., M. N. Eliot, J. Gold, R. R. Vanderslice, and G. A. Wellenius. 2016. Current and projected heat-related morbidity and mortality in Rhode Island. Environmental health perspectives 124:460-467.

Kirtman, B., S. B. Power, J. A. Adedoyin, G. J. Boer, R. Bojariu, I. Camilloni, F. Doblas-Reyes, A. M. Fiore, M. Kimoto, G. A. Meehl, M. Prather, A. Sarr, C. Schär, R. Sutton, G. J. van Oldenborgh, G. Vecchi, and H. J. Wang. 2013. Near-term climate change: Projections and predictability. Pages 953–1028 In Stocker, T. F., D. Qin, G. -. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, editors. Cambridge University Press, Cambridge, UK, and New York, NY, USA.

Knowlton, K., M. Rotkin-Ellman, G. King, H. G. Margolis, D. Smith, G. Solomon, R. Trent, and P. English. 2009. The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. Environmental health perspectives 117:61-67.

Kovats, R. S., and S. Hajat. 2008. Heat stress and public health: A critical review. Annual Review of Public Health 29:41-55.

Lave, L., and E. Seskin. 1977. Air pollution and human health. RFF Press, .

Lebel, L., J. M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. P. Hughes, and J. Wilson. 2006. Governance and the capacity to manage resilience in regional social-ecological systems. Ecology and Society 11:.

Leung, L. R., and W. I. Gustafson. 2005. Potential regional climate change and implications to U.S. air quality. Geophysical Research Letters 32:L16711.

Mann, M. E., Z. Zhang, M. K. Hughes, R. S. Bradley, S. K. Miller, S. Rutherford, and F. Ni. 2008. Proxy-based reconstructions of hemispheric and global surface temperature variations over the past two millennia. Proceedings of the National Academy of Sciences of the United States of America 105:13252-13257.

Matte, T. D., K. Lane, and K. Ito. 2016. Excess mortality attributable to extreme heat in New York City, 1997-2013. Health Security 14:64-70.

McCollum, D. L., V. Krey, K. Riahi, P. Kolp, A. Grubler, M. Makowski, and N. Nakicenovic. 2013. Climate policies can help resolve energy security and air pollution challenges. Climatic Change 119:479-494.

Medina-Ramón, M., A. Zanobetti, D. P. Cavanagh, and J. Schwartz. 2006. Extreme temperatures and mortality: Assessing effect modification by personal characteristics and specific cause of death in a multi-city case-only analysis. Environmental health perspectives 114:1331-1336.

Meehl, G. A., C. Tebaldi, and D. Adams-Smith. 2016. US daily temperature records past, present, and future. Proceedings of the National Academy of Sciences of the United States of America 113:13977-13982.

Melillo, J. M., S. D. Frey, K. M. DeAngelis, W. J. Werner, M. J. Bernard, F. P. Bowles, G.

Pold, M. A. Knorr, and A. S. Grandy. 2017. Long-term pattern and magnitude of soil carbon feedback to the climate system in a warming world. Science 358:101-105.

Merte, S. 2017. Estimating heat wave-related mortality in Europe using singular spectrum analysis. Climatic Change 142:321-330.

Ministries, W., R. D. Bullard, P. Mohai, R. Saha, and B. Wright. 2007. Toxic wastes and race at twenty: 1987-2007. :.

Mohai, P., D. Pellow, and J. T. Roberts. 2009. Environmental Justice. Annual Review of Environment and Resources 34:405-430.

Mora, C., B. Dousset, I. R. Caldwell, F. E. Powell, R. C. Geronimo, C. R. Bielecki, C. W. Counsell, B. S. Dietrich, E. T. Johnston, and L. V. Louis. 2017. Global risk of deadly heat. Nature Climate Change 7:501-506.

Morello-Frosch, R., M. Pastor, J. Sadd, and S. B. Shonkoff. 2009. The climate gap: Inequalities in how climate change hurts americans & how to close the gap. University of California, Berkeley, and USC Program for Environmental & Regional Equity. .

Morello-Frosch, R., M. Zuk, M. Jerrett, B. Shamasunder, and A. D. Kyle. 2011. Understanding the cumulative impacts of inequalities in environmental health: Implications for policy. Health affairs 30:879-887.

Morini, E., A. Touchaei, B. Castellani, F. Rossi, and F. Cotana. 2016. The impact of albedo increase to mitigate the urban heat island in Terni (Italy) using the WRF model. Sustainability 8:999.

Nahlik, M. J., and M. V. Chester. 2014. Transit-oriented smart growth can reduce life-cycle environmental impacts and household costs in Los Angeles. Transport Policy 35:21-30.

Nearing, M. A., F. F. Pruski, and M. R. O'Neal. 2004. Expected climate change impacts on soil erosion rates: A review. Journal of Soil and Water Conservation 59:43-50.

Nordgren, J., M. Stults, and S. Meerow. 2016. Supporting local climate change adaptation: Where we are and where we need to go. Environmental Science & Policy 66:344-352.

Notaro, M., K. Holman, A. Zarrin, E. Fluck, S. Vavrus, and V. Bennington. 2013. Influence of the Laurentian Great Lakes on regional climate. Journal of Climate 26:789-804.

O'Brien, K. L., and R. M. Leichenko. 2000. Double exposure: Assessing the impacts of climate change within the context of economic globalization. Global Environmental Change 10:221-232.

Olen, B., J. Wu, and C. Langpap. 2016. Irrigation decisions for major West Coast crops: Water scarcity and climatic determinants. American Journal of Agricultural Economics 98:254-275.

Perez, T. M., J. T. Stroud, and K. J. Feeley. 2016. Thermal trouble in the tropics. Science 351:1392-1393.

Pierce, J. C., W. W. Budd, and N. P. Lovrich Jr. 2011. Resilience and sustainability in US urban areas. Environmental Politics 20:566-584.

Pincetl, S., M. Chester, and D. Eisenman. 2016. Urban heat stress vulnerability in the US Southwest: The role of sociotechnical systems. Sustainability 8:.

Pye, S., A. Dobbins, C. Baffert, J. Brajković, I. Grgurev, R. De Miglio, and P. Deane. 2015. Energy poverty and vulnerable consumers in the energy sector across the EU: Analysis of policies and measures. European Commission, Insight_E. Stockholm, Sweden.

Ramamurthy, P., and M. Sangobanwo. 2016. Inter-annual variability in urban heat island intensity over 10 major cities in the United States. Sustainable Cities and Society 26:65-75.

Riley, K., H. Wilhalme, L. Delp, and D. P. Eisenman. 2018. Mortality and morbidity during extreme heat events and prevalence of outdoor work: An analysis of community-level data from los angeles county, california. International journal of environmental research and public health 15:580.

Roberts, J. T., and M. M. Toffolon-Weiss. 2001. Chronicles from the environmental justice frontline. Cambridge University Press, .

Rojas-Downing, M., A. P. Nejadhashemi, T. Harrigan, and S. A. Woznicki. 2017. Climate change and livestock: Impacts, adaptation, and mitigation. Climate Risk Management 16:145-163.

Santamouris, M. 2015. Analyzing the heat island magnitude and characteristics in one hundred asian and australian cities and regions. Science of The Total Environment 512-513:582-598.

Schnell, J. L., and M. J. Prather. 2017. Co-occurrence of extremes in surface ozone, particulate matter, and temperature over eastern North America. Proceedings of the National Academy of Sciences of the United States of America 114:2854-2859.

Schulte, P. A., A. Bhattacharya, C. R. Butler, H. K. Chun, B. Jacklitsch, T. Jacobs, M. Kiefer, J. Lincoln, S. Pendergrass, J. Shire, J. Watson, and G. R. Wagner. 2016. Advancing the framework for considering the effects of climate change on worker safety and health. Journal of Occupational and Environmental Hygiene 13:847-865.

Serdeczny, O., E. Waters, and S. Chan. 2016. Non-economic loss and damage in the context of climate change: Understanding the challenges. Deutsches Institut für Entwicklungspolitik German Development Institute]. Bonn, Germany.

Sheridan, S. C., and S. Lin. 2014. Assessing variability in the impacts of heat on health outcomes in New York City over time, season, and heat-wave duration. EcoHealth 11:512-525.

Smith, A. B., and R. W. Katz. 2013. U.S. billion-dollar weather and climate disasters: Data sources, trends, accuracy and biases. Natural Hazards 67:387-410.

Sussman, A., B. Rasmussen, and C. Siddiqui. 2016. Integrating climate change into scenario planning. Transportation Research Record: Journal of the Transportation Research Board 2572:78-85.

Taha, H. 2017. Characterization of urban heat and exacerbation: Development of a heat island index for California. Climate 5:59.

The International Federation of Red Cross and Red Crescent Societies. 2019. The heatwave guide for cities. The International Federation of Red Cross and Red Crescent Societies. .

Tomlinson, C. J., L. Chapman, J. E. Thornes, and C. J. Baker. 2011. Including the urban heat island in spatial heat health risk assessment strategies: A case study for Birmingham, UK. International Journal of Health Geographics 10:42.

Trombley, J., S. Chalupka, and L. Anderko. 2017. Climate change and mental health. AJN The American Journal of Nursing 117:44-52.

Twigg, J. 2009. Characteristics of a disaster-resilient community: A guidance note (version 2). :.

Tyler, S., and M. Moench. 2012. A framework for urban climate resilience. Climate and development 4:311-326.

United States. Environmental Protection Agency. Environmental Equity Workgroup. 1992. Environmental equity: Reducing risk for all communities: Report. US Environmental Protection Agency, Office of Policy, Planning and Evaluation, .

Vahmani, P., A. D. Jones, and C. M. Patricola. 2019. Interacting implications of climate change, population dynamics, and urban heat mitigation for future exposure to heat extremes. :.

van Vuuren, D. P., J. Edmonds, M. Kainuma, K. Riahi, A. Thomson, K. Hibbard, G. C. Hurtt, T. Kram, V. Krey, and J. F. Lamarque. 2011. The representative concentration pathways: An overview. Climatic Change 109:5-31.

Varotsos, C. A., and Y. A. Mazei. 2019. Future temperature extremes will be more harmful: A new critical factor for improved forecasts. International journal of environmental research and public health 16:.

Vicuna, S., R. Leonardson, M. W. Hanemann, L. L. Dale, and J. A. Dracup. 2008. Climate change impacts on high elevation hydropower generation in California’s Sierra Nevada: A case study in the Upper American River. Climatic Change 87:123-137.

Warner, K., and T. Afifi. 2014. Where the rain falls: Evidence from 8 countries on how vulnerable households use migration to manage the risk of rainfall variability and food insecurity. Climate and Development 6:1-17.

Wheeler, T., and J. von Braun. 2013. Climate change impacts on global food security. Science 341:508-513.

White-Newsome, J., S. McCormick, N. Sampson, M. Buxton, M. O'Neill, C. Gronlund, L. Catalano, K. Conlon, and E. Parker. 2014. Strategies to reduce the harmful effects of extreme heat events: A four-city study. International Journal of Environmental Research and Public Health 11:1960-1988.

Yang, J., Z. Wang, and K. E. Kaloush. 2015. Environmental impacts of reflective materials: Is high albedo a "silver bullet" for mitigating urban heat island? Renewable and Sustainable Energy Reviews 47:830-843.

Yates, D., J. Meldrum, and K. Averyt. 2013. The influence of future electricity mix alternatives on southwestern US water resources. Environmental Research Letters 8:045005.