Title

Heat Resilience Planning in San Diego: Local Plans, Barriers, and Tools to Facilitate Strategy Implementation

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Abstract

Heat resilience strategies are necessary to protect against adverse heat impacts in urban environments as extreme heat continues to increase in frequency and intensity due to climate change. Urban planners play a key role in designing and implementing these strategies, and collaboration across agencies and jurisdictions is crucial to building more effective heat governance. The City of San Diego's Climate Resilient San Diego plan includes heat resilience strategies that the City plans to implement in the next five years, which include expanding access to Cool Zones, increasing the urban tree canopy, creating an urban greening program, and implementing cool pavement, cool roofs, and green roofs.

The purpose of this project was first to understand San Diego heat resilience plans and policies, which was accomplished by a review of applicable California State policy and relevant San Diego plans. The next aim was to identify barriers that City of San Diego urban planners face in implementing heat resilience strategies and understand what strategies they believe should be prioritized and what tools may be useful to facilitate action. This was accomplished by conducting a survey of the City of San Diego Planning department. Lastly, these survey responses were used to develop a tool that will help the City meet stated goals in the Climate Resilient San Diego plan and make it easier to implement heat resilience strategies to achieve the most effective outcomes. The tool format is interactive ArcGIS maps and a StoryMap created for the City to use and integrate throughout relevant plans. The results of these maps identify recommended priority zip codes for City planners to consider implementing community outreach and heat resilience strategies based on heat susceptibility and different variables correlating with their heat resilience strategies. Recommendations were made based on survey results, map findings, and heat resilience planning best practices explored through applicable research.

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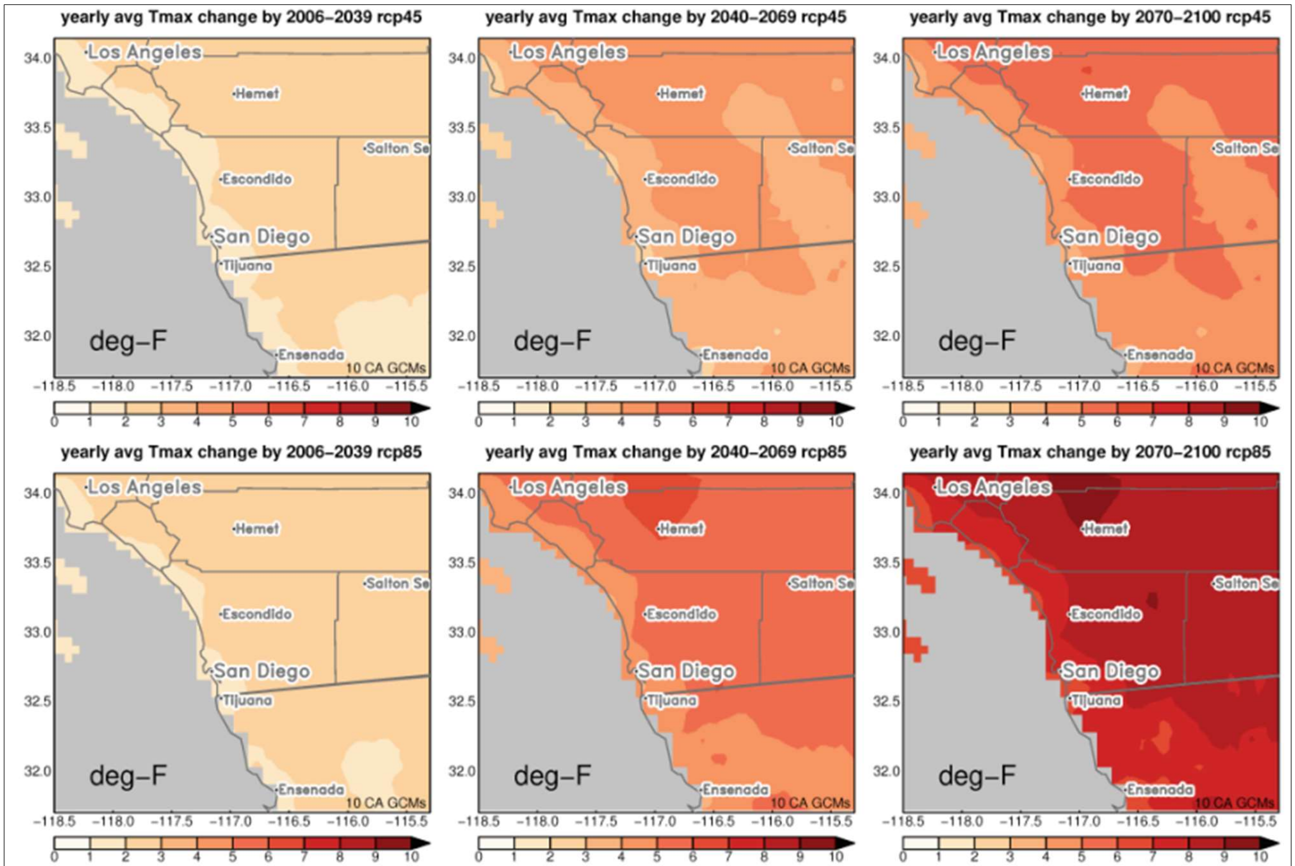
INTRODUCTION AND BACKGROUND

Climate Change and Extreme Heat

As global temperatures rise due to human caused climate change, the impacts will be felt on human health, infrastructure, economies, ecosystems, and habitats. One major impact of climate change is extreme heat, which is projected to increase in frequency and intensity as global warming continues (IPCC, 2022). The Intergovernmental Panel on Climate Change (IPCC) states with high confidence that hot extremes have intensified in cities and place stress on infrastructure systems while posing a health threat to economically and socially vulnerable populations (IPCC, 2022). According to a recent IPCC report, *Climate Change 2021: The Physical Science Basis*, the outlook for cities in the lens of extreme heat is not promising without integrated adaptation measures. The report discusses with high confidence that cities should expect to see an increase in more frequent hot extremes and more severe heatwaves, exacerbated by continued urbanization (IPCC, 2021). Urban environments are particularly vulnerable to heat impacts due to the micro-urban heat island effect, which occurs due to the high amount of non-reflective, heat absorbing materials that make up our cities and reduced cooling effects due to less vegetation cover (Schinasi et al., 2018). This combination of factors can exacerbate heat and cause warmer temperatures in cities.

The Pacific Northwest Heat Dome, an unprecedented heat wave for the region, raged across Oregon and Washington in late June and early July of 2021 (Fountain, 2021). Temperatures soared, breaking records by as much as 5º C (about 9º F) higher than previous temperatures (Fountain, 2021). This event exposed vulnerabilities in heat response plans, communication systems, as well as long term planning and infrastructure solutions. Additionally, in late April through May of 2022, India and Pakistan experienced an extreme heat event, measuring the highest average temperatures since recording started over a hundred years ago (Kaiser & Ward, 2022). Events such as these push the upper limits of heat resilience and will only become more frequent and intense as human-induced climate change continues, with more widespread and deadly consequences. Immediate and long-term planning solutions are crucial to building heat resilience and preventing heat illness, injury, and death, as well as protecting against other infrastructure and impacts. Urban planners play an important role in the creation, implementation, and adjustment of these heat resilience strategies in local plans, and work at the nexus between heat resilience and planning. As climate change impacts worsen, planners' responsibilities will continue to develop and grow more dynamic.

In California, heatwaves are responsible for the largest number of climate-related deaths over the last thirty years (Thorne et al., 2018). California's Fourth Climate Change Assessment, the latest report, predicts increases of the average daily temperature in California of 2.7º F from the historical average until 2039 and 5.8º F from 2040 to 2069 if greenhouse gas emissions continue at current rates (projection based on Representative Concentration Pathway RCP 8.5) (Thorne et al., 2018). In the San Diego County region, yearly average temperatures are expected to increase as much as 4-6 ºF (about 2.2-3.3 ºC) by 2100 under the RCP 4.5 scenario (moderate emission scenario) or up to 7-9 ºF (about 3.6-5 ºC) under RCP 8.5 scenario (high emission scenario) (Kalansky et al., 2018), displayed in **Figure 1** below. Other related climate vulnerabilities that compound extreme heat include drought and wildfire, and wildfires may trigger Public Safety Power Shutoff (PSPS) events, which may impact air conditioning access across the state when shutoffs occur due to high temperatures and high winds that put the state at risk of wildfires (*Utility Public Safety Power Shutoff Plans*, 2021).



A map showing the average Tmax increase at early, mid and end of century relative to 1976-2005 climatology for RCP 4.5 (top) and RCP 8.5 (bottom).

Figure 1*: Maps displaying different RCP scenario impacts on the yearly average maximum temperature in California for 2006-2039, 2040-2069, and 2070-2100. Source: Kalansky et al. (2018).*

The City of San Diego's Climate Resilient San Diego (CRSD) plan and other related climate action and emergency response plans include heat resilience strategies that the City is planning to implement in the next five years. With the increasing threat of extreme heat and a shift towards more focused and equitable heat resilience planning driven by recent California legislative policy updates, planners have a key role in designing and employing strategies locally to prevent adverse heat impacts. The purpose of this project was first to *understand local San Diego heat resilience plans and policies,* which was accomplished by a review of applicable California State policy and relevant San Diego plans. The next aim was to *identify barriers that City of San Diego urban planners face in implementing heat resilience strategies* and *understand what strategies they believe should be prioritized and what tools may be useful to facilitate action.* This was accomplished by conducting a survey of the City of San Diego Planning department. Lastly, these survey responses were used to *develop a tool that will help the City meet stated goals in the Climate Resilient San Diego plan and make it easier to implement heat resilience strategies to achieve the most effective outcomes.* The tool format is interactive ArcGIS maps that display the overlap and combination of both daytime and nighttime heat susceptibility with variables that align with heat resilience strategies in the CRSD plan, including Cool Zones, tree canopy cover, and impervious surface cover. The methods and details for these research aims and results will be discussed in depth in subsequent sections.

The structure of this paper consists of a discussion on the health impacts of heat and San Diego specific context in the introduction, followed by a heat resilience planning section, then a thematic literature review. The literature review will conclude with an overview of San Diego heat resilience planning and move into the discussion of the City of San Diego survey design and analysis, followed by a description of data that was used for the ArcGIS maps, ArcGIS maps, discussion of findings, and concluding with recommendations.

Health Impacts

Heat is the deadliest climate-related cause of death and can be prevented in many scenarios with effective planning and response, which requires coordination across sectors (*Extreme heat*, 2021). Heat related illness and death occurs when the body is not able to sufficiently cool itself, causing the body temperature to rise, potentially damaging vital organs and the brain (*About Extreme Heat*, 2017). The Centers for Disease Control and Prevention (CDC) states that those most at risk include older adults, young children, and people experiencing mental illness and chronic diseases (*About Extreme Heat*, 2017), though anyone can be impacted by heat. Other populations that face vulnerabilities to heat include people with disabilities, outdoor workers, those experiencing social isolation, homelessness, and people without air conditioning.

Some health impacts caused by heat exposure include heat rashes, cramps, exhaustion, and heat stroke, which is the most serious heat related condition (Abbinett et al., 2020). Heat stroke requires medical treatment and occurs when the internal body temperature rises to 104º F or higher (Abbinett et al., 2020) as a result of not being able to cool itself. This severe medical condition impacts the function of the central nervous system and can result in death (Abbinett et al., 2020). In addition, heat can also worsen pre-existing conditions such as renal, cardiovascular, and respiratory conditions, adding to the increase in emergency medical service calls and emergency department visits that typically occur during extreme heat (Abbinett et al., 2020). An average of about 650 heat-related deaths occurred in the United States every year from 1999-2009, though this is likely an underestimation that only represents direct impacts, as death records do not often include heat exposure as a causal factor (Abbinett et al., 2020). Shindell et al. (2020) predict a large increase in premature death from heat exposure as warming continues, highlighting the need for integrated heat resilience strategies that address vulnerable populations. The IPCC also predicts an increase in heat-related deaths without the implementation of resilience strategies as well as an increase in mental health issues such as anxiety and stress (IPCC, 2022).

Urban environments and lack of air conditioning may exacerbate heat impacts and put populations at risk due to compounding heat effects. Indoor temperatures can grow warmer than outdoor temperatures without air conditioning, which can lead to high temperatures remaining for days following the end of a heat event (Abbinett et al., 2020). Increasing access to air conditioning, while a crucial public health and equity issue, also has implications on electricity demand that need to be carefully considered as urban environments and populations grow.

San Diego Context

Sheridan et al. (2012) project future heat vulnerability in the state of California, and their results found an increase in heat events throughout the remainder of the century, including heat events of two weeks or longer being up to ten times more common in coastal locations (Sheridan et al., 2012). While the study found a general increase in heat events, their results focusing on coastal regions are pertinent for this project's concentration specifically on San Diego.

San Diego consists of diverse climate zones and regions that experience different levels of heat vulnerability and risk (Gershunov & Guirguis, 2012). Coastal residents routinely experience different temperatures and weather conditions, and health impacts are seen at lower temperatures closer to the coast compared to further inland (Gershunov & Guirguis, 2012). In San Diego, hospitalizations occurred at higher rates and lower temperatures along the coast than in inland regions during heat events (Gershunov & Guirguis, 2012). This is likely due to air conditioning not being as common on the coast as in inland regions due to the generally mild coastal temperature, which leaves residents less adjusted to heat and more vulnerable to its impacts (Gershunov & Guirguis, 2012). Additionally, coastal residents show increased vulnerability earlier in the early season due to loss of heat acclimatization in the winter (Guirguis et al., 2014).

California's heat waves, which are projected to increase in humidity and intensity, particularly for nighttime temperatures, will have impacts on human health, ecosystems, agriculture, water resources, energy demand, and infrastructure (Gershunov & Guirguis, 2012). Clemesha et al. (2018), discusses the coastal impact and explains that most intense heat waves across a region begin at the coast, move inland, and weaken at the coast. Additionally, less cooling at night means less relief from the heat, and during heat events that span numerous days, the lack of cooling relief can exacerbate heat impacts (Kalansky et al., 2018). Gershunov and Guirguis discuss specifically the difference in heat wave presentation between coastal and inland regions, which creates uneven impacts throughout the state. Heatwave season is typically seen in July for inland regions, whereas in coastal regions the peak is usually seen in September. This is due to the Santa Ana winds which cause more frequent and intense heat events later in the season due to the trapping of dry coastal air (Gershunov & Guirguis, 2012). Additionally, the observed nighttime temperatures are increasing in all regions, which pose a greater health risk, especially for those without air conditioning.

With the awareness of San Diego's unique climate zones and differing resulting impacts based on location, National Weather Service (NWS) San Diego created new criteria that focus on climate zones and the weather's difference from the normal climate in that geographic region, in order to account for seasonal changes or norms (Guirguis et al., 2014). Additionally, the NWS created an Experimental HeatRisk forecast map that displays heat concern for an area throughout the Western United States, coded by color and corresponding with a level of heat concern (*NWS Experimental HeatRisk*, n.d.). This forecast is being used to help with the decision to issue heat watches, advisories, and warnings and supplements other NWS heat programs.

Just as the NWS adjusted their criteria in consideration of different climate zones and acclimatization, planners should also consider these factors and the demonstrated and historical heat impacts on an area when designing heat resilience solutions to implement. The next section will introduce heat resilience planning solutions followed by a literature review on the topic.

HEAT RESILIENCE PLANNING

Planning Solutions Introduction

To avoid the worst impacts of extreme heat, the implementation of integrated solutions designed to address vulnerabilities and provide co-benefits is crucial. Climate change adaptation at the local level relies greatly on urban and environmental planners, as they can incorporate adaptation strategies into city plans that support a host of health and social services, promote resilient infrastructure, address land use issues, and community-based adaptation (IPCC, 2022). Resilience is defined as the capacity of systems to cope with and respond to a hazardous event while maintaining the capacity for adaptation, learning, or transformation, which is adapted from the IPCC's definition. In its discussion of heat resilience planning, the IPCC states that heat action plans are an effective short-term adaptation option for extreme heat risks and recommends the integration of longer-term urban design strategies that influence the urban environment (IPCC, 2022). When implementing both short- and long-term strategies, a multi-sectoral approach, including the engagement of a range of stakeholders is crucial to success and ensuring buy-in (IPCC, 2022).

The American Planning Association's (APA) recent report, "Planning for Urban Heat Resilience" provides planners with information about heat as a climate change hazard, a planning framework, and "comprehensive approaches" to address heat in local communities (Keith & Meerow, 2022). The APA report defines two key terms, heat management and heat mitigation, which will be used throughout this report as well to identify different approaches to addressing heat. Heat management includes strategies that typically fall in the realm of public health and disaster management and response that are focused on communication/messaging, preparation, and response to heat events. Some of these strategies include *educational campaigns, warning and notification systems, heat action plans, and increasing access to cooling centers and indoor cooling resources* (Keith & Meerow, 2022).

Educational campaigns can help to inform residents of the health risks of extreme heat and of resources and strategies to keep themselves safe, and can be carried out through social media, community outreach, and early warning and notification systems. Heat action plans, identified by the IPCC as an effective short term heat resilience strategy, typically involve a coordinated set of steps that local stakeholders take in the event of extreme heat that clearly designate roles and actions to help reduce heat-related illness and death (Keith & Meerow, 2022). Cooling centers are public locations, usually libraries or recreation centers, that provide free air conditioning and respite from extreme heat. When implementing Cool Zones or Cool Zone networks, it is important to consider the accessibility of these spaces to people with diverse needs, as well as transportation assistance to and from locations (Keith & Meerow, 2022). Finally, access to indoor cooling, which may include air conditioning, coolers, and fans, is a crucial public health measure that remains inaccessible to many. The cost of purchasing and running these systems can be unsustainable for many people, and measures to help with energy bill payment assistance, such as the Low Income Home Energy Assistance Program (LIHEAP), or free or loan air conditioning and fan programs are crucial to help vulnerable populations stay cool (Keith & Meerow, 2022).

Heat mitigation is defined in this report as urban design and planning strategies that reduce the contribution of the built environment to urban heat. These strategies generally have longer term implementation times and are focused on improving the urban environment. The main urban heat mitigation strategies include *increasing the urban tree canopy, implementing green roofs, urban greening programs, and implementing cool pavements and roofs*. Increasing the urban tree canopy and urban greening can help with lowering surface and air temperatures through the process of evapotranspiration and by providing shade (EPA, 2021), which has a cooling effect. Other co-benefits of increasing trees and vegetation are improved air quality, improved stormwater retention, and reduced need for air conditioning on nearby residences (EPA, 2021).

Green roofs are vegetative layers or gardens grown on a rooftop (EPA, 2021) that can help to reduce the urban heat island effect by reducing the amount of dark, heat absorbing materials in an urban environment. They can also reduce building cooling requirements, provide stormwater retention, aesthetic value, and even edible landscapes that could benefit a community. Cool pavement and cool roofs increase the albedo, or reflectivity of a surface, typically by using lighter colored materials or paint over the roof or pavement surface. These strategies can help improve thermal comfort and reduce energy use needed for air conditioning (EPA, 2021). **Figure 2** below displays a useful graphic of heat mitigation and management strategies.

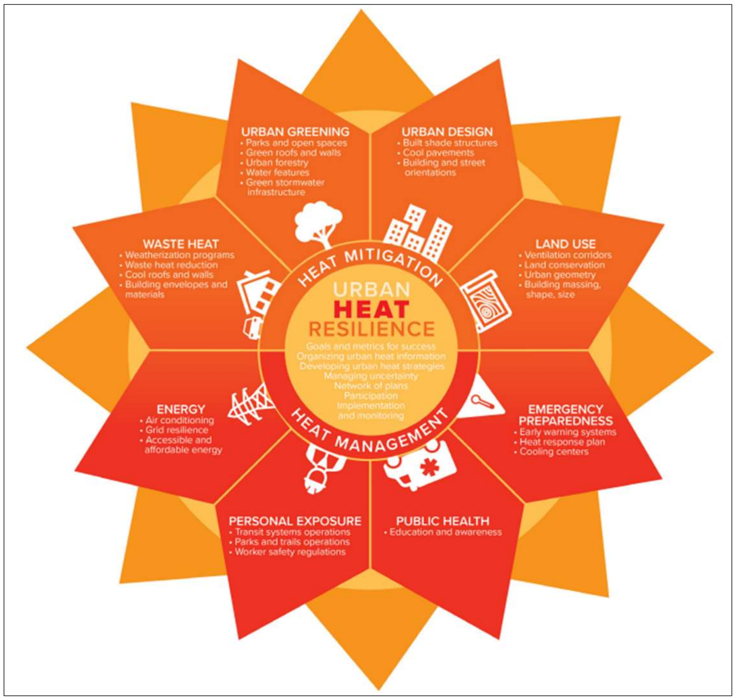


Figure 2: *Urban Heat Resilience Strategies, Source: Keith & Meerow, (2022).*

Studies have been completed to measure the effectiveness of urban heat mitigation strategies such as adoption of cool roofs, drought-tolerant vegetation, and cool pavement application in Southern California, a Mediterranean climate. Regarding adoption of cool roofs, Vahmani et al. (2016) indicate that widespread adoption of cool roofs can lead to both day and night temperature reductions. Drought tolerant vegetation was found to have a net cooling effect in Los Angeles, a very similar climate, though it may cause increased day temperatures (Vahmani & Ban-Weiss, 2016). On a smaller, neighborhood level scale, increasing street vegetation and adopting cool pavements had the largest effect on decreasing the air temperature (Taleghani et al., 2016).

When discussing heat management and mitigation strategies, incorporating the component of equity is imperative to the planning process. Areas that were historically redlined remain the hottest neighborhoods in many cities today, with larger amounts of impervious surfaces and less green space and tree canopy coverage (Feola, 2021). These disparities lead to disproportionate health impacts in these communities, which can be deadly when it comes to extreme heat.

In addition to less vegetation and tree canopy coverage, residents in these areas may also lack access to indoor cooling resources that provide critical relief during heat. Planner's awareness of how needs differ across neighborhoods- whether heat mitigation or heat management strategies should be prioritized based on existing conditions and feedback from community outreach- is crucial to effectively cooling neighborhoods and reducing the health burden of heat (Keith & Meerow, 2022). Equity will be discussed in more detail in the local policy context and recommendations sections.

The next section is a broad, thematic literature review exploring different areas of heat resilience planning including management/implementation of strategies, heat vulnerability indexes and mapping, and best practices from other cities. The section will conclude with a review of the current heat resilience planning landscape in San Diego.

LITERATURE REVIEW

Management and Implementation of Heat Resilience Strategies

Frameworks for considering the management and implementation of heat resilience planning are clearly addressed by the work of Meerow and Woodruff (2019), which explores progress in the areas of climate change mitigation and adaptation planning through evaluation of selected U.S. resilience and adaptation plans and proposes seven principles for strong climate change planning. While focused on the topics of climate change and adaptation planning, the research and principles are still broadly applicable to heat resilience planning. Meerow and Woodruff (2019) propose more coordinated planning across sectors and stricter processes for the implementation and monitoring of plans. They argue that strong climate change planning requires support from diverse stakeholders, including representatives from local universities, different levels of government, the private sector, nongovernmental organizations, and neighboring jurisdictions (Meerow & Woodruff, 2019). Their seven principles for strong climate change planning include: clear goals, strong fact base, diverse strategies, public participation, coordination across actors, sectors, and plans, processes for implementation and monitoring, and techniques to address uncertainty (Meerow & Woodruff, 2019).

Leiter et al. (2021) also highlight the importance of integrated planning for climate change hazards with a proposed framework for collaborative and science-based climate resilience planning. The framework emphasizes broad focus areas, including infrastructure, natural resources, coastal resources, public safety, and public health (Leiter et al., 2021). These frameworks can be implemented on differing scales, though the key principles are that there is an understanding of regional climate change impacts and interconnectedness, integration of environmental justice and equity, and identifying plans that require climate impact analysis. A key takeaway from this report is the proposal for "vertically and horizontally integrated plans" (Leiter et al., 2021) which allow for identification of vulnerabilities across and within plans and provide future opportunities for collaborative planning to better address them. In their discussion of heat resilience planning, they mention the importance of addressing compounding extreme events, such as drought and wildfire, in plans. These practices in addition to the seven principles from Meerow and Stults provide excellent frameworks for developing integrated plans that include monitoring and addressing multiple hazards through less fragmented plans.

Meerow and Keith (2021) explore heat planning and governance through a survey of planning professionals across the U.S. to better understand barriers to heat resilience planning and identify opportunities to enhance strategy implementation. The study identified opportunities to connect planners to heat information sources and tools that would aid them in implementing plans that lessen risk (Meerow & Keith, 2021). Some common barriers that were identified in the study include lack of coordination and regulations on heat; fragmented institutions, political leadership, public support and human and capital resources; low prioritization of heat and uncertainties as to what strategies are most effective; and funding, time, and staff (Meerow & Keith, 2021).

Keith et al. (2020) also identify some common challenges for successful heat resilience planning, including siloed heat governance, research that limits cross-governmental and interdisciplinary collaboration, complex heat resilience strategies, and "the need to combine heat 'risk management' strategies and design of the built environment" (Keith et al., 2020, para. 1). The barriers highlighted in both Meerow and Keith (2021) and Keith et al. (2020) are important indicators of areas of potential areas of improvement for local governments and stakeholders to focus on to advance their plans. Additionally, Keith et al. (2020) asserts that planning for heat resilience will need to take on a "nested governance" approach to allow for multi-sector and multi-scale planning, ranging from micro-climate to regional level.

In another piece, Keith et al. (2021), propose a dedicated program to support heat governance, introducing six principles for leadership to address barriers and enhance implement best practices for heat resilience. The six principles include advance heat equity, mitigate heat, manage risks, develop metrics, coordinate initiatives, and improving heat governance on a national and local scale (Keith et al., 2021). They recommend that more developed hazard planning areas, such as flooding, be studied to gather best practices and apply applicable lessons to heat. Additionally, they propose a research program to better understand what needs to be developed to support heat across all levels of government (Keith et al., 2021). Some cities such as Phoenix, Miami, and Los Angeles have created positions for chief heat officers at their local governments in order to support and oversee the implementation of heat related strategies, though it is clear that more research to support understanding what effective heat governance looks like is needed.

From the previous studies, there are some common barriers identified and recommendations made in order to improve heat resilience planning, which include *plan integration across multiple sectors and hazards* and *metrics for the implementation and monitoring of plans.* These key takeaways will be discussed further in the report, including recommendations for how to integrate them within the City of San Diego's current plans.

Lastly, *Planning for Urban Heat Resilience* provides a comprehensive overview of heat resilience, including an in-depth introduction to heat and its numerous impacts, best practices for implementation, a planning framework, and priority areas for future research. Their framework for addressing heat includes the two common recommendations identified above, coordination across planning efforts and monitoring and evaluating the effectiveness of heat resilience strategies (Keith & Meerow, 2022). They state that the integration of heat resilience plans should include addition into community plans, infrastructure plans, and other plans influencing urban development and closely involve the coordination of stakeholders such as planners; departments of public works, parks and recreation, and transportation; utilities; nonprofits focused on expanding nature-based solutions; and private developers (Keith & Meerow, 2022).

Keith and Meerow (2022) also assert that heat resilience strategies should maximize co-benefits, and, to incorporate recommendations from Leiter et al. (2021), strategies should both maximize co-benefits and integrate with other climate change hazards to holistically address multiple hazards. The report also discusses the use of public health information to provide indications of whether heat mitigation and management strategies are effective at reducing impacts. The use of this data would provide planners with information that would allow them to adjust strategies periodically to increase effectiveness, preventing adverse heat impacts. They also identify some priority areas for research, including heat planning and governance roles, effectiveness and interactions of heat mitigation and management strategies, heat modeling and mapping for planners and improving heat-health outcomes (Keith & Meerow, 2022).

Heat Vulnerability Indexes and Mapping

Heat vulnerability indexes (HVI) are popular tools that are being created for use by municipalities and public health departments to understand risk and target priority areas for heat resilience strategies. This section will review the effectiveness of HVIs and recommendations for improvements and future research.

Bao et al. (2015) reviews the construction and validation of HVIs and found that they can be useful for targeting areas based on heat risk, and monitoring of heat and health outcomes could help to improve the HVI in the future. Additionally, there is more research required to fully understand which heat indicators are most useful for inclusion in the index, and how to use indexes to apply and alter planning solutions as necessary. They also discuss some potential dangers of utilizing HVI, which could "become little more than mathematical expressions of an eloquent conceptual model of vulnerability if they are not confronted with observational data and testing" (Bao et al., 2015, para 23). Overall, they state that HVIs can be helpful in identifying priority areas for planners and municipal leaders to focus on, though should be frequently updated and improved to validate health outcomes (Bao et al., 2015).

Chuang and Gober (2015) discuss the usefulness of HVIs for public health and other municipal workers to identify risks at a neighborhood level, and then distribute resources and planning solutions in areas of greatest priority and need. They also assert that the usefulness of a HVI can be sensitive to the scale at which it is being applied, and studied how indicators of heat risk were interrelated in Phoenix, AZ. Their results found that "low socioeconomic status, as well as the proportion of adults > 65 years of age living alone, percentage of adults living alone, and the rate of hospitalization for diabetes, predict vulnerability to heat at the census-tract level" (Chuang & Gober, 2015, para. 28), and these can be used to help their city improve heat resilience strategies. However, their findings suggest the importance of place-specific vulnerability indicators, identified based on predicting hospital admissions, to determine the risk of adverse effects in their cities (Chuang & Gober, 2015).

Johnson et al. (2012), also discusses the importance of developing HVIs on a local level that considers place-based social and environmental vulnerabilities. They emphasize that the nature of heat vulnerability is specific to different climate zones and locations within cities, and that the biggest limitation in current specific heat warnings is the absence of "spatial specificity" when determining how different areas may experience risk (Johnson et al., 2012).

Another important topic in the discussion of HVIs is how, or if, they can influence local heat resilience policies. Wolf et al. (2015) explores if a gap exists between research and practice in implementing local strategies that are developed from results of heat vulnerability studies, and found that heat vulnerability mapping appears to succeed in bringing awareness to municipalities, but is less successful in triggering the implementation of heat resilience strategies (Wolf et al., 2015). Overall, they point to the need for integrating science into decision making in order to inform policy development, which can be done by stakeholders working together to better understand barriers to both communities in achieving their goals, and then working together to co-produce outcomes and implementation pathways.

Fragomeni et al. (2020) builds on this idea, stating that researchers may assume that their results and recommendations will be integrated into practice, though their work does not always capture the need of practitioners and translate it into a usable product. This study creates a framework that will help climate scientists and planners coordinate needs and produce useable knowledge and products, allowing them to "develop and apply data in collaboration with decision makers" (Fragomeni et al., 2020, para. 3). Another key piece in addition to communication and understanding the need between planners and scientists is identifying stakeholders in the right departments that need to be part of these conversations and collaboration.

Best Practices from other Cities

Cities across the U.S. are implementing heat resilience plans to protect against adverse heat impacts. Studying their plans and what strategies align with the literature is an effective way to understand what new strategies could be successful in San Diego, and perhaps provide detail on implementation pathways that could advance their execution. Additionally, as strategies develop over time and monitoring and tracking of effectiveness occurs, lessons learned from strategies that don't work will be useful in adjusting plans. This section will explore some best practices and recommendations for San Diego based on existing heat resilience strategies.

Boston, Massachusetts- Heat Resilience Solutions for Boston, the city's newest heat resilience report released in April 2022 provides the city's vision, goals, and strategies to address extreme heat. The city developed an Extreme Temperature Steering Group that consisted of the Office of Public Health Preparedness, the Office of Emergency Management, and Office of Environment as well as an Extreme Temperature Advisory Group consisting of over 100 participants and utilized a three-phase planning process to develop the plan, including: 1. Analysis and existing information review, 2. Heat resilience strategies, and 3. Implementation roadmap and final report (City of Boston, 2022). Stakeholders provided significant input community feedback was integrated into the planning process, which included a survey open to the public. The report makes it clear that the heat plan "builds on and complements" recent and in-progress climate plans and mentions compounding climate change hazards such as coastal flooding (City of Boston, 2022). The city researched future temperature predictions given different emission scenarios and conducted a weeklong, citywide heat analysis to understand how heat affects different areas in the city. In addition to their community outreach through surveys, fan distributions, and workshops, they identified gaps in the existing cooling networks, and chose focus neighborhoods to conduct a detailed study of solutions in five of the hottest neighborhoods.

They conducted a heat analysis for each focus neighborhood, evaluating daytime and nighttime heat temperatures, community engagement sessions, and proposed heat resilience "opportunities" or strategies. An example of some strategies proposed include integration of "pocket" green spaces, cool/shaded pavement and surface parking, indoor cooling network, and resilient design principles for new developments (City of Boston, 2022). These strategies represent a mix of both heat management and heat mitigation strategies and demonstrate throughout the plan the integration of stakeholders necessary to achieve cooling solutions in an area.

Boston's Heat Resilience Plan is a good example of an overarching, cohesive heat resilience plan that incorporates many of the best practices and strategies for planning mentioned in the literature review, including coordinated planning across sectors and stakeholders.

Los Angeles, California is implementing numerous heat management and mitigation strategies across the city to protect residents from heat impacts. They are leading the charge on the installation of cool pavement in California, and starting in 2017, Streets LA, the Bureau of Street Services, began installing cool pavement coating to one city block in each of the 15 Council Districts. In May 2019, the first neighborhood- level cool pavement project was completed, including cool pavement seal on 11 residential blocks. The cool pavement coating produced an average of reduction in surface temperature by 10º F (StreetsLA, 2021). Their next actions include applying cool pavement and shade trees across eight underserved neighborhoods in the community, which were selected by utilizing the Trust for Public Lands Climate Smart Cities Mapping Tool for Los Angeles, the Google Tree Canopy Tool, and the Tree Equity Tool (StreetsLA, 2021). The selection criteria for these neighborhoods was a combination of high heat and low tree canopy, with additional factors taken into consideration such as neighborhoods impacted by pollution and other environmental stressors (StreetsLA, 2021).

New York City (NYC), the largest city in the United States and a vast urban environment, is facing projections of up to a 5.7°F increase in average temperatures and a doubling of the number of days above 90°F by the 2050s according to The New York City Panel on Climate Change (NPCC) (City of New York, 2017). Implementing heat management and mitigation solutions is crucial for the City to build resilience, especially as it is more vulnerable to heat impacts due to the large amount of impervious surface cover, which exacerbates the urban heat island effect. NYC has implemented heat mitigation strategies such as street tree planting, NYC Cool Roofs program, which coats roofs with white paint to improve their reflectivity and provide heat relief, applying cool pavement coating, and implementing multi-benefit green infrastructure (City of New York, 2017). NYC developed a *Million TreesNYC* program, which included collaboration among the NYC Department of Parks and Recreation, NYC Mayor's Office of Recovery and Resiliency, NYC Department of Health and Mental Hygiene, Natural Areas Conservancy, Urban Systems Lab at The New School, and The State University of New York at Buffalo and provided strategy and implementation plan for tree planting goals (City of New York, 2017). The City has also implemented heat management to help inform and protect residents from the harmful impacts of heat, including the 'Be a Buddy Program'. This program is a partnership between key agencies including the NYC Department of Health and Mental Hygiene, the NYC Mayor's Office of Recovery and Resiliency, and NYC Emergency Management, which seeks to improve the response capacity and preparedness of at-risk neighborhoods (The City of New York, 2017). This program involves training community organizations on ways to assist vulnerable adults in extreme heat situations as well as conducting outreach in these communities to identify neighborhood resources to help keep residents cool and safe (The City of New York, 2017).

Philadelphia has a similar heat management program called "Heatline" which is activated during heat emergencies and allows people to call in who are then informed about heat stress and can refer those in need to emergency services. It also deploys mobile teams in response to Heatline calls and is activated when the Health Commissioner for Philadelphia calls a heat emergency for the city (Philadelphia Mayor's Office of Sustainability & ICF, 2015). These programs were established in coordination with Philadelphia's Office of Emergency Management, and the *Growing Stronger Toward a Climate Ready Philadelphia* plan identifies different City department's vulnerabilities to heat in its plan. The City also has an interactive ArcGIS Heat Vulnerability Index map that contains locations and information on cooling resources, including cooling bus locations, cooling centers, public pools, and public spraygrounds (City of Philadelphia, 2021). The map was created in collaboration with the Philadelphia Department of Public Health and the Mayor's Office of Sustainability. Overall, these strategies serve as good examples of heat management and coordination across City departments and public health stakeholder and provide a variety of cooling resources to the community.

Phoenix, Arizona can be considered a "test-bed" for urban heat resilience, as one of the largest and hottest cities in the Southwest (Hondula et al., 2019). Maricopa County, which contains the City of Phoenix, saw the largest gain in residents of any U.S. county between April 2020 and July 2021, with about 76,000 new residents (Johnson, 2022). As the city and county continue to grow, urban heat resilience strategies and coordinated management and mitigation plans are crucial to protecting Phoenix residents from heat-related injury and death, as well as adapting the urban environment to be able to withstand rising temperatures and the demands of a growing population. Air conditioning is a key adaptation measure that makes the desert environment livable for many, though as the City grows there will be a greater demand on the energy grid, especially during extreme heat. Solar adoption remains high in Arizona and federal and state incentives will need to continue to encourage residents to install photovoltaics in order to reduce the strain on the energy grid and ensure residents have air conditioning access when needed.

Phoenix has appointed a Chief Heat Officer to coordinate heat resilience efforts throughout the city and interface with relevant stakeholders, implement tracking metrics, and help to develop additional heat resilience policies (Hondula et al., 2019). In addition, the City of Phoenix has a partnership with Arizona State University (ASU) to track the performance of its cool pavement application and partnership on other related research and projects (Hondula et al., 2019). These two developments demonstrate the importance of heat governance and collaboration that will need to become more common in cities facing extreme heat to successfully adapt.

PROJECT AIMS AND GENERAL METHODOLOGY

Project Aims

As demonstrated through the introduction and following sections, heat resilience planning and associated best practices are in development and being tested and improved through studies and municipal implementation. With the evolving policy landscape around heat resilience and lack of central coordinating agency, the imperative for stakeholders to work together to ensure integration across plans is crucial to combatting the worst impacts of heat in our communities.

This project aims to meet the following objectives:

- **Understand local San Diego heat resilience plans and policies.**
- **Identify barriers that City of San Diego urban planners face in implementing heat resilience strategies.**
- **Understand what strategies planners believe should be prioritized and what tools may be useful to facilitate action.**
- **Develop a tool that will help the City meet stated goals in the Climate Resilient San Diego plan and make it easier to implement heat resilience strategies to achieve the most effective outcomes.**

General Methodology

The methodology to meet these objectives includes a few different steps that build off each other. The first was a local policy review and analysis, which was done through policy research followed by a review of applicable planning documents, including the Climate Resilient San Diego Plan, City of San Diego Climate Action Plan [DRAFT], County of San Diego Multi-Jurisdictional Hazard Mitigation Plan, and County Excessive Heat Response Plan. Following this, a survey was created for City of San Diego Planning Department to better understand their use of related tools, what strategies they believe should be prioritized, barriers to heat resilience planning, as well as identifying a tool that would aid in strategy implementation. The survey results were collected, analyzed, and used to create ArcGIS maps and a StoryMap, intended for use by City of San Diego planners to aid with implementation of heat resilience strategies. Lastly, the maps as well as research components of this project were used to formulate recommendations based on findings to advance heat resilience planning in San Diego.

LOCAL POLICY CONTEXT

A local policy review was conducted by first researching statewide policy around heat resilience planning, then focusing on local policies within San Diego.

California State Policy and Plans

Senate Bill 1035- In 2018, Senate Bill 1035 was approved and requires that after 2022, cities and counties must revise their general plan safety elements to identify new information on fire hazards, flood hazards, and climate adaptation and resiliency strategies applicable to the jurisdiction that were not available during the previous revision of the safety element (*SB-1035 General plans*, 2018). The review or update can take place at the same time as the housing element or local hazard mitigation plan update but must be updated every eight years at a minimum (DeShazo et al., 2021). While not explicitly stated that extreme heat needs to be included in municipalities' plans, extreme heat is a major climate threat across the state and should be included in municipalities planning actions and documents. Currently, at the county and city level, the Local Hazard Mitigation Plan (LHMP) and Safety Element of a General Plan are the only required planning documents to include action plans designated climate hazards.

Senate Bill 1000- Senate Bill 1000, approved September 24, 2016, requires all cities' general plans to include an environmental justice (EJ) element that identifies disadvantaged communities and to identify objectives and policies to reduce health risks in these communities. It also requires the identification of objectives and policies that address the needs of disadvantaged communities (*SB 1000*, 2016). This legislation has implications for planners and adds important factors to consider as they move forward with planning objectives and goals. The City of San Diego is currently in the process of updating its Environmental Justice (EJ) Element for its General Plan, and planned to start community engagement in the Spring of 2022, with the next steps being policy development and community feedback. They've conducted an EJ Background Review that provides detailed maps and breakdown of different EJ elements in San Diego, to include climate change and resilience. The document includes maps of land surface temperature maps, tree canopy coverage and cooling centers, impervious surface cover, and energy cost burden, which could be significant points of integration with the findings in this report. As new legislation is passed that impacts planning for climate change and disadvantaged communities, the importance of collaboration between agencies and jurisdictions that's been highlighted in this report grows in magnitude.

CA Extreme Heat Action Plan- In April 2022, the Extreme Heat Action Plan was released to provide a comprehensive, inter-agency plan that will help Californians build resilience to extreme heat (State of California, 2022). This plan divides actions into four categories: 1) Build Public Awareness and Notification, 2) Strengthen Community Services and Response, 3) Increase Resilience of our Built Environment, and 4) Utilize Nature-Based Solutions (State of California, 2022) and includes recommended actions for the state to take to address extreme heat. In particular, the state plans to focus its primary efforts on implementing a statewide public health monitoring system, accelerating readiness and protection of communities most affected by extreme heat, protecting vulnerable populations through codes, regulations, and standards, expanding economic opportunity and build a climate smart workforce, increase public awareness, and protect natural and working lands, ecosystems, and biodiversity (State of California, 2022). The detailed plan also highlights coordinating agencies in its goals, demonstrating the inclination for collaboration on these plans and aligning with best practices in the literature for effective heat planning. The statewide policies in this plan are discussed in depth, and the plan states that implementing this wide range of policies will require a lot of time, funding, and effort (State of California, 2022). The Extreme Heat Action Plan will be integrated with California's Climate Adaptation Strategy and will be tracked through the strategy's annual implementation reporting process, so municipalities can check in on the progress to understand how this will help with their planning efforts.

San Diego Policy and Plans

A review of San Diego's climate action and resilience plans, adopted between 2017 and 2022, was conducted to identify current heat resilience strategies and their integration across similar plans. Results were compiled from the following sources and categorized in the table below: Climate Resilient San Diego plan (CRSD) (2021), Climate Action Plan (CAP) (2022 draft), San Diego County Multi-Jurisdictional Hazard Mitigation Plan (MJHMP) (2017), and San Diego County Excessive Heat Response Plan (EHRP) (2021). The County plans were included because the County's LHMP has jurisdiction over the City for their hazard/disaster response. Additionally, it's important to note that the City's Safety Element of its General Plan was updated in December 2021, and it identifies the County's Multi-Hazard Mitigation Plan and the CRSD plan as the primary planning documents for hazard mitigation planning to meet state requirements for planning for climate change hazard adaptation and resilience (City of San Diego, 2021).

The organization of policies in **Table 1** below is grouped by *tree canopy/urban forest/shade, built environment, and general heat response/cooling*. The first two categories are considered heat mitigation and general heat response/cooling is considered heat management.

Legend

CRSD: Climate Resilient San Diego, (City of San Diego, 2021)
CAP: Climate Action Plan [Draft], (City of San Diego, 2022)
MJHMP: Multi-Jurisdictional Hazard Mitigation Plan [County Document], (County of San Diego, 2017)
EHRP: Excessive Heat Response Plan [County Document], (County of San Diego Health and Human Services Agency, 2021)

Plan	Policy	Timeframe
Tree Canopy/Urban Forest/Shade (Heat Mitigation)		
CRSD	(Policy Thriving Natural Environments (TNE)-6) "Protect and expand the City's urban forest."	Near
CRSD	(Policy TNE-6) "Incorporate considerations for a changing climate into urban forestry management and planning. Update the Urban Forestry Program 5 Year Plan with consideration for tree species diversification, salt tolerance, and irrigation needs."	Near

CRSD	(Policy TNE-6) "Maintain and expand the City's urban tree canopy to meet the City's Climate Action Plan goals."	Near, Ongoing
CAP	(Strategy 5, Measure 5.2) "Conduct a new Urban Tree Canopy assessment utilizing light detection and ranging (LiDAR) technology to identify areas in need of additional tree canopy."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Create a Street Tree Master Plan with a target of planting 100,000 trees by 2035 capturing all community plan street tree lists to facilitate selection of species (in relation to the No Fee Permit). Within the Street Tree Master Plan, identify City lands and spaces that need trees and identify ways to increase permeable areas for new trees, focused in Communities of Concern."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Increase tree planting in Communities of Concern by identifying City lands/spaces that need trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Support expansion of urban tree canopy in parks and along active transportation network. Prioritize implementation in Communities of Concern."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Develop policies that encourage and incentivize developers, homeowners associations, and other organizations to preserve, maintain, and plant trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Reform and expand the free tree program."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 5, Measure 5.2) "Protect and maintain existing trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Amend the Land Development Code to increase landscape and parking lot tree planting requirements."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Revise No Fee Street Tree Permit Application to help improve process for obtaining street trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover

CAP	*(Strategy 5, Measure 5.2) "Streamline permitting for tree planting, dedicate resources to planting in nontraditional street tree locations, and provide reduced fees or fee waivers for concrete cutting in Communities of Concern."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Revise Council Policies and Municipal Codes to strengthen tree protection and enhance tree planting efforts."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Increase irrigation for trees in Parks and in Street rights-of-way."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Implement a Citywide protocol for tracking planted, removed, and maintained street trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Explore allocating revenue from tree removal fines, including from the placement of utility equipment located in the right-of-way, and fees to fund the planting of new trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Expand volunteer programs and partnerships with community organizations to plant and maintain trees."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	*(Strategy 5, Measure 5.2) "Support the creation of new urban green space along freeways and City rights-of-way."	-2030: 28% Urban Tree Canopy Cover -2035: 35% Urban Tree Canopy Cover
CAP	(Strategy 3, Measure 3.2) "Strategize and Implement a street furniture program that reduces heat exposure, provides cool transit stops, and improves access to restrooms in high transit use areas/pedestrian corridors prioritizing Communities of Concern."	-2030: 19% walking and 7% cycling mode share -2035:25% walking and 10% cycling mode share
CAP	(Strategy 3, Measure 3.2) "Transit shelters: Ensure every high-volume transit stop has access to shade structures and benches; establish standard for bus shelters in the city (minimum accommodations) with a priority on Communities of Concern."	-2030: 19% walking and 7% cycling mode share resident trips -2035:25% walking and 10% cycling mode share
CRSD	(Policy RE-2) "Increase access to parks and open space for all San Diegans. Increase overall shaded area at park spaces. Natural shade from trees shall be prioritized over artificial shade structures whenever feasible."	Near, Ongoing

Built Environment (Heat Mitigation)		
CAP	(Strategy 5, Measure 5.3) "Amend building code regulations to require a percentage of all non-roof (e.g., hardscape) surfaces around new buildings meet certain criteria to reduce urban heat island effect."	(based on PureWater project water supply goals)
CAP	(Strategy 5, Measure 5.3) "Install cool pavement material on City streets, prioritizing Communities of Concern, to increase building energy efficiency and reduce urban heat island effect."	(based on PureWater project water supply goals)
CRSD	(Policy RE-2) "Incentivize installation of cool roofs and green roofs."	Near, Ongoing
CRSD	(Policy CCS-3): "Plan for a climate ready transportation network."	Near, Ongoing
CRSD	(Policy RE-2) "Develop an urban greening program to promote expanded green spaces in urban areas. The program should facilitate greening of City buildings and encourage private development to include green features through policy development or incentive programs."	Mid
General Heat Response/Cooling (Heat Management)		
CRSD	(Policy RE-5) "Coordinate with the County of San Diego Department of Public Health on Cool Zones program. Provide easily accessible locations, particularly in Communities of Concern. Expand access to Cool Zones, shade corridors, and the coast."	Near, Ongoing
CRSD	(Policy RE-2) "Utilize the Urban Heat Vulnerability Index to help inform implementation of adaptation strategies to address extreme heat events and identify priority areas for cooling interventions."	Near
CRSD	(Policy CCS-3) "Account for high heat days when planning City staff duties to minimize exposure to extreme heat and/or provide necessary protective measures.	Near, Ongoing
MJHMP	(Goal 11, Objective 11B) "Protect vulnerable populations from the effects of extreme heat."	
MJHMP	(Goal 11, Objective 11B, Action 11.B.1) "Support regional efforts to prepare for extreme heat events"	
MJHMP	(Goal 11, Objective 11B, Action 11.A.2) "Participate in "Excessive Heat Emergency Awareness" events and exercise heat emergency plans as established by HHSA, AIS, EMS, and PHS."	

MJHMP	(Goal 11, Objective 11B, Action 11.A.3 "Continue to provide "Cool Zones" during excessive heat events."	
EHRP	(1-Cool Zones) "the County designates Cool Zone sites, air-conditioned settings where seniors and others can gather. The sites, mostly located in the hottest areas of the county, encourage people to share air conditioning during the heat of the day, lowering individual usage and helping to conserve energy for the whole community."	
EHRP	(2- Cool Zones Fan Program) "the County of San Diego, in partnership with SDG&E, provides free electric fans to those who are living on limited incomes. To be eligible, a resident must not have access to an air-conditioned space at their home or apartment building."	
EHRP	(3-Transportation) During an excessive heat event 2-1-1 San Diego will maintain a list of available transportation resources that will transport County residents to and from Cool Zone locations. This is coordinated through various partners. There is no charge for participation in this program."	

Table 1*: San Diego Heat Resilience Planning Policies.*
* Supporting Action defined in the CAP

Analysis

Overall, it is clear through the numerous heat management and heat mitigation strategies across the examined plans that San Diego is focused on heat resilience. However, integration of these plans and an understanding of how they work together when focus areas and goals overlap is not clear, as well as who has ultimate tracking and implementation responsibilities. While helpful tools already existed prior to this project and were created as part of this project to aid planners in the implementation of these strategies, coordination across stakeholders and plans is crucial to ensuring successful implementation and tracking to understand effectiveness.

Although not utilized specifically for this project, the Plan Integration for Resilience Scorecard (PIRS) framework allows practitioners to study the integration of plans across a community. PIRS facilitates the understanding of where and how plans interact, allowing practitioners to better align future plans and remove conflicting policies (DeAngelis et al., 2021). A Plan Integration for Resilience Scorecard for Heat (PIRSH) is currently in development and will be helpful to evaluate integration of strategies across plans by providing information on how to map spatial distribution of strategies, combine heat risk data, and identify opportunities for improvement across plans (Keith & Meerow, 2022). PIRSH could also aid planners in eliminating overlap between plans, such as various CRSD and CAP tree canopy strategies, to ensure for more clear and concise goals with designated stakeholders overseeing all related efforts. Additionally, utilizing this method in the future could also help to identify integration points for future related plans such as the EJ element.

SURVEY DISCUSSION AND ANALYSIS

Introduction

A survey was created and distributed to better understand City of San Diego planners' relationship with planning for heat resilience, including their familiarity and use of planning tools, what strategies they believe should be prioritized, local barriers to implementing supporting actions, and potential tools that would be helpful to advance effective strategy implementation.

Survey Design

The survey contained eight questions total (see **Appendix 1**) and was designed to take about five minutes to complete. It was sent electronically, via internal City of San Diego email to the Planning Department and a few select personnel who were involved with the Climate Resilient San Diego plan, as identified and included by Jordan Moore. The survey was first sent out on March 22, 2022 to 75 personnel, with a reminder email sent about two weeks following that, on April 4, 2022 and there were 26 respondents total for a 34% response rate.

It was optional for survey respondents to include their name, department, and current projects they are involved with in order to better understand the range of respondents and the different focus areas that they represent.

Questions number three and six in the survey were adapted from survey questions (numbers 8 and 13, respectively) in "Planning for Extreme Heat: A National Survey of U.S. Planners" (Meerow & Keith, 2021). The Capstone Chair, Tarik Benmarhnia, Ph.D., one postdoctoral researcher, Katie Crist, Ph.D., and Capstone Advisor Jordan Moore reviewed and provided input on the survey prior to sending it out. The Qualtrics online platform was used for the survey, and results were analyzed utilizing their visualization and report tools.

Survey Results

The first two questions allowed survey respondents to put their name, City department and position, and current projects that they are involved with if desired. The third question provided a list of current heat mapping tools and allowed planners to select which (if any) were currently in use. The mapping tool that is utilized by most planners was a *vegetation or tree canopy map*, at 55% of respondents saying that it was in use, followed by the *San Diego Climate Equity Index*[1] *Heat Vulnerability Map*, at 47.4%. Results are displayed below in **Figure 3.**

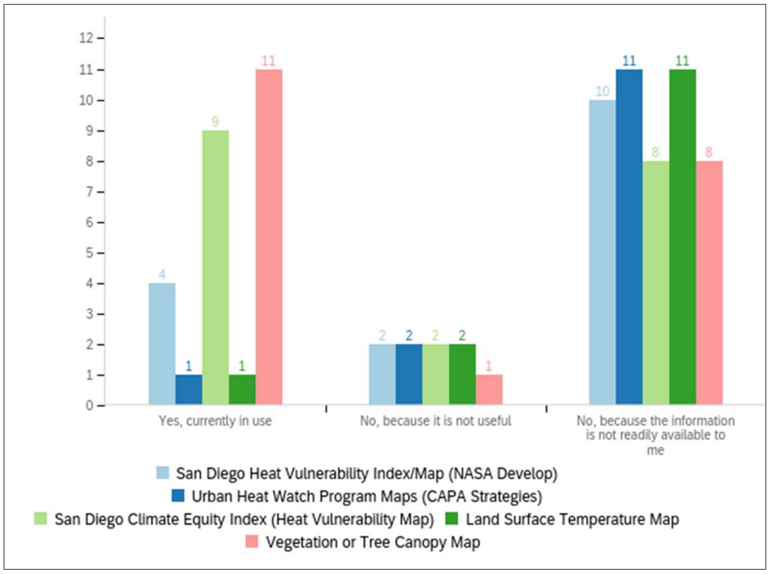


Figure 3*: Survey Question #3 Response Chart. Are the following sources of data or information on extreme heat used in the project(s) that you previously or are currently working on?*

The next question involved a Likert scale in order to assess how comfortable respondents felt utilizing different types of tools such as vulnerability indexes, ArcGIS maps, and other sources of data. As shown in Figure 4, 13 respondents reported feeling *somewhat comfortable*, 6 felt *extremely comfortable*, 3 felt *neither comfortable nor uncomfortable*, 2 felt *somewhat comfortable*, and 2 felt *extremely uncomfortable*.

[1] Climate Equity Index: https://usandiego.maps.arcgis.com/apps/webappviewer/index.html?id=6438f83d648a4126bae695f2b06871bc

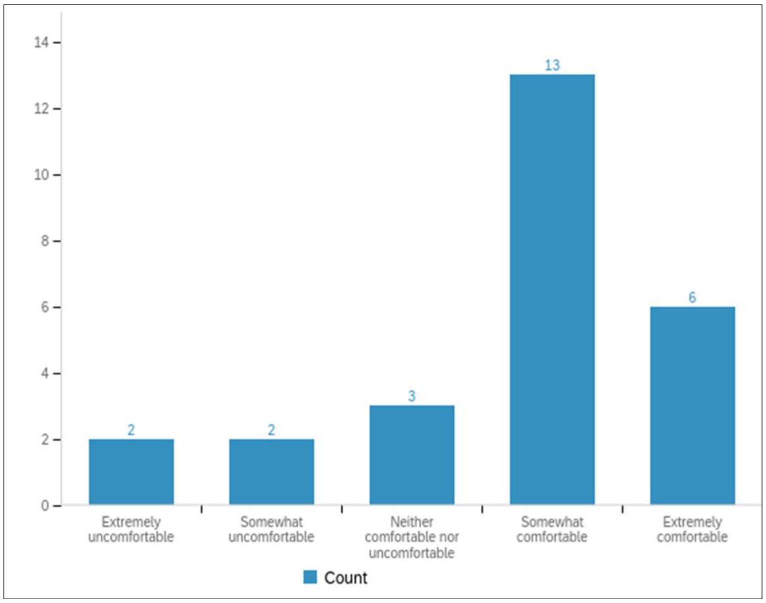


Figure 4: *Question #4 Response Chart. How comfortable do you feel using tools such as vulnerability indexes, ArcGIS maps, and other sources of data to make planning decisions?*

The next question was a ranking of what heat adaptation strategies should be prioritized in San Diego. Most respondents, 65.2%, ranked *increase urban tree canopy* as their first choice, followed by *install green roofs* as the second option at 13.04%, then *install cool roofs* and *install cool pavement*, both at 8.7%. **Figure 5** below displays the results of the question.

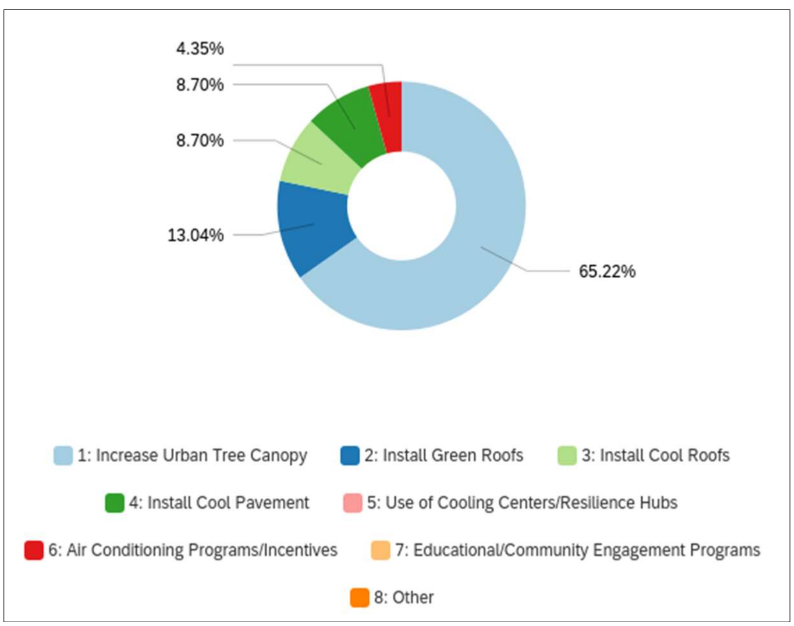


Figure 5: *Question #5 Responses, Which heat adaptation strategies should be prioritized in San Diego?*

The next question was intended to gain an understanding of the barriers to implementing heat resilience planning in San Diego. Responses could be ranked from significant barrier, moderate barrier, slight barrier, and not a barrier.

The following categories were identified as *significant barriers* by most respondents: funding, time and staff, and leadership. Coordination between agencies and jurisdictions, available data and tools on extreme heat risk, and other hazards or issues being higher priority were the top responses for *moderate barriers*. Knowledge of heat strategies, public support, and leadership were identified as the *top slight barriers*. **Figure 6** below displays the responses and rankings.

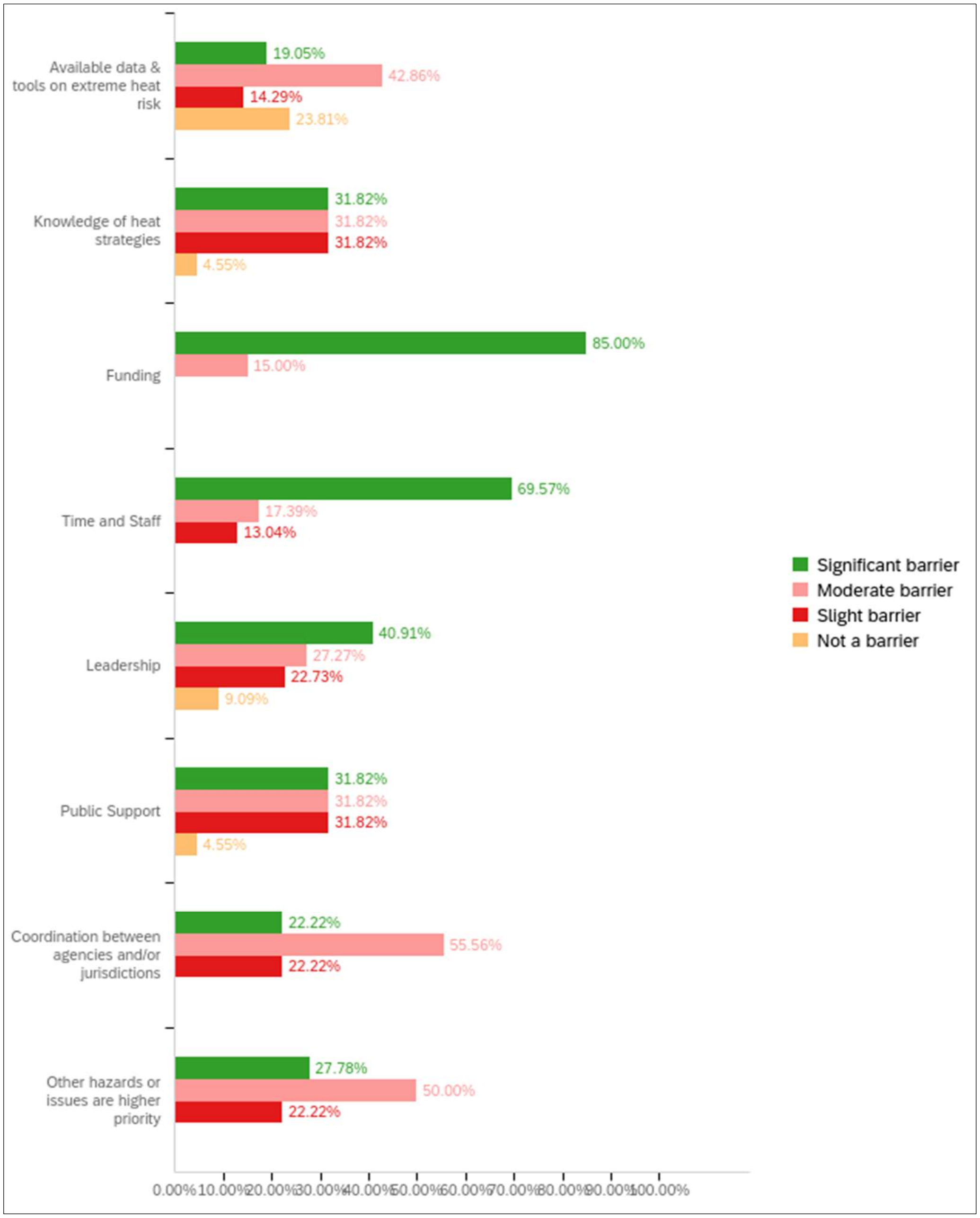


Figure 6: *Question #6 Response Graph, To what degree to you consider the following as barriers to heat resilience planning in San Diego or in the communities that you work with?*

The last question was designed to understand what types of tools may be helpful in facilitating the implementation of heat resilience strategies by ranking. Respondents could rank which strategies they believe would be most helpful on a scale of 1 to 5. The top strategy that was identified was *a visualization tool about heat-related impacts in San Diego to identify communities most affected by heat risk*, followed by a *prioritization matrix for heat adaptation strategies,* and *a tool to understand the ranking of heat events for each neighborhood*. **Figure 7** below displays the question responses and rankings for each strategy.

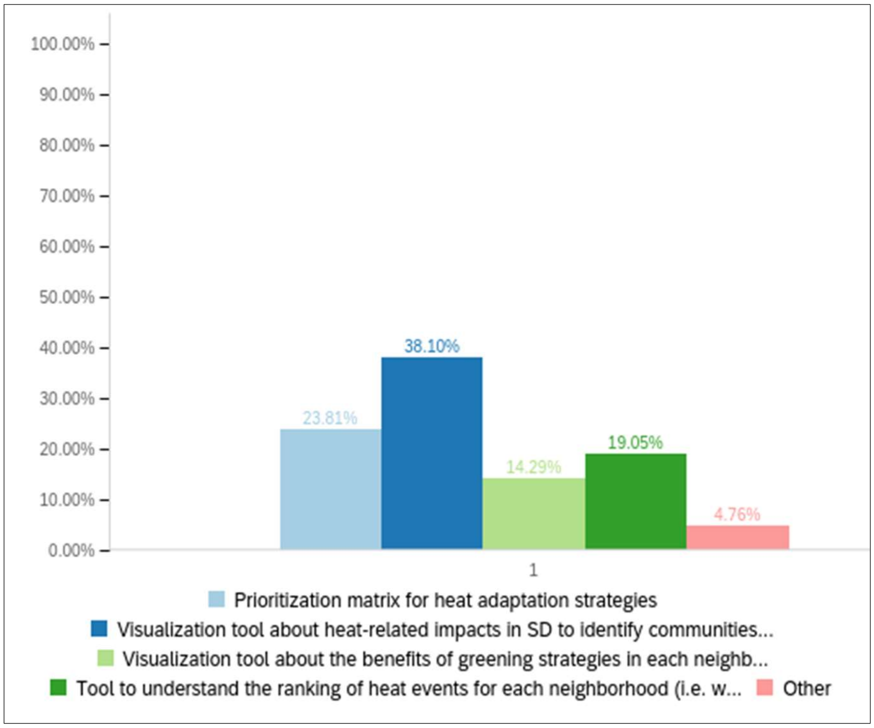


***Figure 7**: Survey Question #7 Responses Graph, What other tools may be helpful in facilitating the implementation of heat adaptation strategies? (responses ranked first displayed only)*

Survey Analysis

This section discusses the survey results in greater depth and provides an analysis that shapes the recommendation for tool creation.

The top source of data or information used by planners as identified in the survey was the *vegetation/tree canopy map*, a response that correlates with the top answer for which heat resilience strategies should be prioritized. This response was not unexpected based on the number of related strategies across the CRSD and CAP plans regarding increasing the urban tree canopy/ urban forest. The second most popular response was the San Diego Climate Equity Index Heat Vulnerability Map. This interactive ArcGIS map allows users to view an Urban Heat Island Index overlay as well as percent tree canopy cover and select other socioeconomic and health burden factors at the census tract level.

The next question helped to gain an understanding of planners' comfort level with different planning tools that may aid in more effective implementation. It also helped with determining the type of tool to create as the majority responded that they are *somewhat comfortable* utilizing tools such as ArcGIS maps.

For what strategies planners believe should be prioritized, the top response of increasing the urban tree canopy aligns with the current volume of related goals across the CRSD and CAP. The CRSD plan includes goals of expanding the City's urban forest/tree canopy, as well as increasing access to shade in three of its policies, while the CAP has 17 policies relating to trees (see **Table 1**). Additionally, the second most common response, installing green roofs, is a stated policy in the CRSD and CAP. One interesting question that the results prompt is: why are heat management strategies, such as *educational/community engagement programs, air conditioning programs/incentives, and use of cooling centers/resilience hubs*, ranked so low as priorities by planners? This may point to the need for greater integration of heat management strategies across heat resilience plans at the City level, despite heat management strategies typically being managed by the County.

One plausible reason for this could be that historically, planners in this area may have focused more on heat mitigation strategies that center on altering the urban environment, and heat management strategies may have been planned separately by other agencies or stakeholders. Since County jurisdictions usually take the lead on public health and emergency response in a region, the integration of both heat mitigation and heat management strategies may be lacking. In San Diego, the County maintains the lead on Cooling Centers and is currently working to expand educational programs for Resident Leaders on heat related interventions for the community. Greater collaboration among the City and County to integrate heat mitigation and management strategies might yield a different response to this question in the future. Another reason for this is that planners may see heat management strategies as falling under the purview of different departments that might not be ones that they typically work closely with, which could provide opportunity for further interoperability in the future.

The significant barriers to advance heat resilience planning in San Diego were identified as *funding, time and staff, and leadership*. Though these are important indicators, they are likely not unique to San Diego, and other municipalities likely face similar issues with lack of funding and overburdened staff with not enough time. With the recent FY2023 Budget approval, which allocated funding for a Chief Resiliency Officer who will be responsible for the execution of the Climate Resilient SD plan, there will likely be more dedicated oversight and time to focus on resiliency plans, which may help to remove some of these barriers (City of San Diego, 2022b). Additionally, future funding opportunities may be available that could help eliminate this barrier, as resiliency was awarded 14% of the total amount designated for the Climate Action Plan Fiscal Year 2023 budget, which comes third behind the top allocation, Zero Waste, followed by Strategy 3- Bicycling, Transit, and Land Use (City of San Diego, 2022b). If this survey question was asked a year or two from now, it would be interesting to observe if *funding, time and staff,* and *leadership* would still be the top responses for significant barriers.

Moderate barriers identified were *coordination between agencies and jurisdictions, available data and tools on extreme heat risk, and other hazards or issues are higher priority*. Given the consensus in heat resilience planning literature on the importance of, and often lack of, coordination between agencies and jurisdictions, this answer for top moderate barrier was not a surprising result. With the identification and awareness of this barrier, the City can work closely with other stakeholders and agencies to identify opportunities for collaboration and determine the best ways to improve coordination and communication for future projects. Another tool that could aid in identification and understanding roles of different stakeholders is the development of a stakeholder map. This could help with visualization of all potential stakeholders and how they currently work together, or could in the future, to advance heat resilience planning.

The final question was asked to understand what type of tools may be helpful in facilitating the implementation of heat resilience strategies. *Available data and tools on extreme heat risk* was identified as the second largest moderate barrier to heat resilience planning, and though a variety of interactive tools and data exist, not all of it is specific to or designed for San Diego. The top tool that was identified that would aid in heat resilience strategy implementation was a *visualization tool about heat-related impacts in San Diego to identify communities most affected by heat risk*. The second and third tools identified were *a prioritization matrix for heat adaptation strategies*, and a *tool to understand the ranking of heat events for each neighborhood.*

The survey answers were designed to be somewhat vague for the last question in order to provide some leeway on the exact design of a product or tool. This question helped to get a general sense of what could be helpful, and the intent following that was to co-design it with the City based on other survey results and expressed needs. The tool platform and design was decided based on survey responses on familiarity and comfort level with platforms such as ArcGIS, what strategies planners believed should be prioritized, and what they ranked for potential helpful tools.

HEAT RESILIENCE PLANNING TOOL

The platform and tool functionality was determined based on a few different factors, including:

1. Survey responses
2. Discussion with respondents
3. Alignment with CRSD strategies & potential usefulness for planners in implementing these strategies
4. ArcGIS as a user-friendly and interactive platform

The resulting tool that was created was a set of ArcGIS maps, which were also added to a StoryMap created for the City and include interactive maps that displays factors of distance to Cool Zones, tree canopy cover, and impervious surface cover against daytime and nighttime heat susceptibility by neighborhood. Additionally, relevant heat resilience strategies from the CRSD plan that will be discussed further in the findings and recommendations from the maps include:

- Coordinate with the County of San Diego Department of Public Health on **Cool Zones** program (expand Cool Zone access).

- Maintain and expand the City's **urban tree canopy** to meet the City's Climate Action Plan goals (28% urban tree canopy cover by 2030, 35% by 2035).
- Install **cool pavement** on City streets, prioritizing Communities of Concern, to increase building energy efficiency and reduce urban heat island effect.
- Incentivize installation of **cool and green roofs**.
- Develop an **urban greening program** to promote expanded green spaces in urban areas.

Data Sources for ArcGIS Maps

Zip Code

Zip code data was obtained from the SANDAG GIS Regional Data Warehouse Open Data Portal. The data publication date for zip code data was April 4, 2022 and includes all zip codes in San Diego County. Once I imported the shapefile version of the data into ArcGIS Pro (Version 2.9), I removed all non-City of San Diego zip codes, to include a few zip codes 92134, 92140, and 92145 that were for military installations and bases.

Daytime and Nighttime Heat Susceptibility Data

To obtain zip code estimates of heat susceptibility, we relied on previous work in which the average number of hospitalizations attributable to different extreme heat conditions (more details provided in **Appendix 2)** were estimated, considering events driven by daytime temperatures and nighttime temperatures. These estimates represent the number of hospital admissions that would not be observed in the absence of extreme heat events, which *directly quantifies the heat burden in each community*. We considered 18 different heat definitions to consider different durations, intensity and the temperature metric (daytime or nighttime) and each definition was specific to a given zip code temperature conditions.

Cool Zone data

Cool Zone data was obtained from the SANDAG GIS Regional Data Warehouse Open Data Portal and the publication date was September 24, 2019. The shapefile was imported into ArcGIS Pro, and non-City of San Diego zip codes were removed. The data package was most recently updated on February 7, 2022.

Population weighted centroid layer

The population weighted centroid layer for ArcGIS Pro was obtained from the Department of Housing and Urban Development (HUD) GIS Open Data. The non-applicable zip codes were filtered out and the centroids within the City of San Diego zip codes were used to determine each Cool Zone's distance from them.

Tree canopy

Tree canopy data from Hale (2020) was utilized as it was already converted to the zip code level from the census tract level. Data was obtained from the California Healthy Places Index, which utilized data from the California Department of Public Health.

Impervious Surface

Impervious surface cover data were also obtained from Hale (2020), which was adapted from Schwarz et al. (2021) which utilized Google Earth Engine. The 2006 image was utilized to get an imperviousness estimate for each zip code, which was the only band that correlated with the heat susceptibility data for this project.

Scoring System

A scoring system was created to simply rank and compare variables. The scores range from 1-4, and quartiles were calculated in Microsoft Excel for each factor, including daytime heat susceptibility, nighttime heat susceptibility, Cool Zone distance, tree canopy cover, and impervious surface cover. The 1-4 scores correlate with the following rankings:

1= low
2= medium low
3= medium high
4= high

The combined maps for daytime and nighttime heat susceptibility were created by adding together the scores of each applicable variable. For daytime, those variables were Cool Zone distance, tree canopy cover, and impervious surface cover, and for nighttime they were tree canopy cover and impervious surface cover. For both daytime and nighttime heat susceptibility, applicable scores were added together to get a combined score (16 is the highest score for daytime heat susceptibility, 12 is the highest for nighttime heat susceptibility), and then quartiles were calculated in Microsoft Excel for the combined scores and ranked appropriately.

Table 2 displays scores for daytime heat susceptibility, Cool Zone distance, impervious surface cover, tree canopy cover, and combined scores by zip code. The scores of 1-4 and correlated ranking of low to high are included in the table and can be used as a reference when viewing the maps.

Daytime Heat Susceptibility, Cool Zone Distance, Impervious Surface Cover, Tree Canopy Cover, and Combined Score										
ZIP	Community	Heat Susceptibility	Heat Susceptibility Score	Cool Zone Distance	Cool Zone Distance Score	Impervious Surface Cover	Impervious Surface Cover Score	Tree Canopy Cover	Tree Canopy Cover Score	Combined Score
92037	La Jolla	High	4	High	4	Medium Low	2	High	1	Medium High
92037	La Jolla	High	4	High	4	Medium Low	2	High	1	Medium High
92101	San Diego	High	4	Medium Low	2	High	4	Low	4	High
92102	San Diego	Medium High	3	High	4	High	4	Medium Low	3	High
92103	San Diego	Medium Low	2	Low	1	Medium High	3	High	1	Low
92104	San Diego	High	4	Low	1	High	4	Medium Low	3	Medium High
92105	San Diego	Medium High	3	Low	1	High	4	Low	4	Medium High
92106	San Diego	Medium Low	2	High	4	Medium Low	2	Medium High	2	Medium Low
92107	San Diego	High	4	Low	1	High	4	Medium Low	3	Medium High
92108	San Diego	Low	1	Medium High	3	Medium High	3	High	1	Medium Low
92109	San Diego	High	4	Medium Low	2	Medium Low	2	Low	4	Medium High
92110	San Diego	Medium High	3	Medium High	3	High	4	Medium Low	3	High
92111	San Diego	Medium High	3	Medium High	3	Medium Low	2	Medium High	2	Medium Low
92113	San Diego	Medium Low	2	Medium Low	2	High	4	Low	4	Medium High
92114	San Diego	Medium High	3	High	4	Medium High	3	Low	4	High
92115	San Diego	Medium Low	2	High	4	High	4	Medium High	2	Medium High
92116	San Diego	High	4	Medium High	3	Medium High	3	Medium Low	3	High
92117	San Diego	High	4	Medium Low	2	Medium High	3	High	1	Medium Low
92119	San Diego	Medium Low	2	Medium Low	2	Low	1	Medium Low	3	Medium Low
92120	San Diego	Low	1	Low	1	Medium Low	2	Medium High	2	Medium Low
92121	San Diego	Low	1	High	4	Medium Low	2	High	1	Medium Low
92122	San Diego	Medium Low	2	Medium High	3	Medium Low	2	High	1	Medium Low
92123	San Diego	Low	1	Low	1	Medium High	3	Medium Low	3	Medium Low
92124	San Diego	Low	1	Medium High	3	Low	1	Medium High	2	Low
92126	San Diego	Low	1	Low	1	Medium Low	2	Medium Low	3	Low
92127	San Diego	Low	1	Low	1	Low	1	Medium High	2	Low
92128	San Diego	Medium High	3	High	4	Low	1	High	1	Medium Low
92129	San Diego	Medium Low	2	Low	1	Low	1	Medium High	2	Low
92130	San Diego	Low	1	Medium High	3	Low	1	Medium High	2	Low
92131	San Diego	Medium Low	2	Medium Low	2	Low	1	High	1	Low
92139	San Diego	Medium High	3	High	4	Medium High	3	Low	4	High
92154	San Diego	Medium High	3	Medium Low	2	Low	1	Low	4	Medium Low
92173	San Ysidro	High	4	Low	2	Medium Low	2	Low	4	Medium High

Table 2: *Daytime Heat Susceptibility, Cool Zone Distance, Impervious Surface Cover, Tree Canopy Coverage, and Combined Factors.*

Table 3 displays scores for nighttime heat susceptibility, impervious surface cover, tree canopy cover, and combined scores by zip code.

Nighttime Heat Susceptibility, Impervious Surface Cover, Tree Canopy Cover, and Combined Score								
ZIP	Community	Heat Susceptibility	Heat Susceptibility Score	Impervious Surface Cover	Impervious Surface Cover Score	Tree Canopy Cover	Tree Canopy Cover Score	Combined Score
92037	La Jolla	3	Medium High	Medium Low	2	High	1	Low
92037	La Jolla	3	Medium High	Medium Low	2	High	1	Low
92101	San Diego	2	Medium Low	High	4	Low	4	High
92102	San Diego	4	High	High	4	Medium Low	3	High
92103	San Diego	4	High	Medium High	3	High	1	Medium High
92104	San Diego	1	Low	High	4	Medium Low	3	Medium High
92105	San Diego	2	Medium Low	High	4	Low	4	High
92106	San Diego	2	Medium Low	Medium Low	2	Medium High	2	Low
92107	San Diego	1	Low	High	4	Medium Low	3	Medium High
92108	San Diego	2	Medium Low	Medium High	3	High	1	Low
92109	San Diego	4	High	Medium Low	2	Low	4	High
92110	San Diego	3	Medium High	High	4	Medium Low	3	High
92111	San Diego	1	Low	Medium Low	2	Medium High	2	Low
92113	San Diego	1	Low	High	4	Low	4	Medium High
92114	San Diego	4	High	Medium High	3	Low	4	High
92115	San Diego	3	Medium High	High	4	Medium High	2	Medium High
92116	San Diego	2	Medium Low	Medium High	3	Medium Low	3	Medium High
92117	San Diego	4	High	Medium High	3	High	1	Medium High
92119	San Diego	3	Medium High	Low	1	Medium Low	3	Medium Low
92120	San Diego	3	Medium High	Medium Low	2	Medium High	2	Medium Low
92121	San Diego	1	Low	Medium Low	2	High	1	Low
92122	San Diego	1	Low	Medium Low	2	High	1	Low
92123	San Diego	2	Medium Low	Medium High	3	Medium Low	3	Medium High
92124	San Diego	3	Medium High	Low	1	Medium High	2	Low
92126	San Diego	4	High	Medium Low	2	Medium Low	3	Medium High
92127	San Diego	4	High	Low	1	Medium High	2	Medium Low
92128	San Diego	3	Medium High	Low	1	High	1	Low
92129	San Diego	4	High	Low	1	Medium High	2	Medium Low
92130	San Diego	3	Medium High	Low	1	Medium High	2	Low
92131	San Diego	2	Medium Low	Low	1	High	1	Low
92139	San Diego	1	Low	Medium High	3	Low	4	Medium High
92154	San Diego	2	Medium Low	Low	1	Low	4	Medium Low
92173	San Ysidro	1	Low	Medium Low	2	Low	4	Medium Low

Table 3: *Nighttime Heat Susceptibility, Impervious Surface Cover, Tree Canopy Cover.*

ArcGIS Maps & Findings

Once scoring was complete, maps were built in ArcGIS Pro using the applicable layers and data, which is detailed for each map below. The bi-variate maps include a legend to help distinguish which colors correlate with what scores, and on the StoryMap, users can select a zip code to see additional score information that is displayed in **Tables 2** and **3**.

Figure 8, Cool Zone Distribution, was created utilizing the zip code ArcGIS layer, population weighted centroid ArcGIS layer, and Cool Zone ArcGIS layer obtained from the SANDAG GIS Warehouse. The blue tabs on the map represent Cool Zone locations, and on the StoryMap users can select them to learn more about Cool Zone operating hours, contact information, and additional site-specific details. This map provides the viewer with a spatial overview of the distribution of Cool Zones without the City, and allows them to identify zip codes that are lacking Cool Zones. Additional context is provided in **Figure 9**, which displays the daytime heat susceptibility and Cool Zone distance for each zip code.

Figure 8: City of San Diego Cool Zone Location Map.

Figure 9, Daytime Heat Susceptibility and Cool Zone Distance Map, was created utilizing the zip code ArcGIS layer and joining the daytime heat susceptibility and Cool Zone distance data by zip code. The darkest shaded zip codes represent those with both high daytime heat susceptibility and high distance to a Cool Zone (from population weighted centroid in each zip code). Zip codes **92037, 92102, 92114, 92139, 92116,** and **92118** (in order) are recommended to be prioritized by the City for addition of a Cool Zone based on these factors.

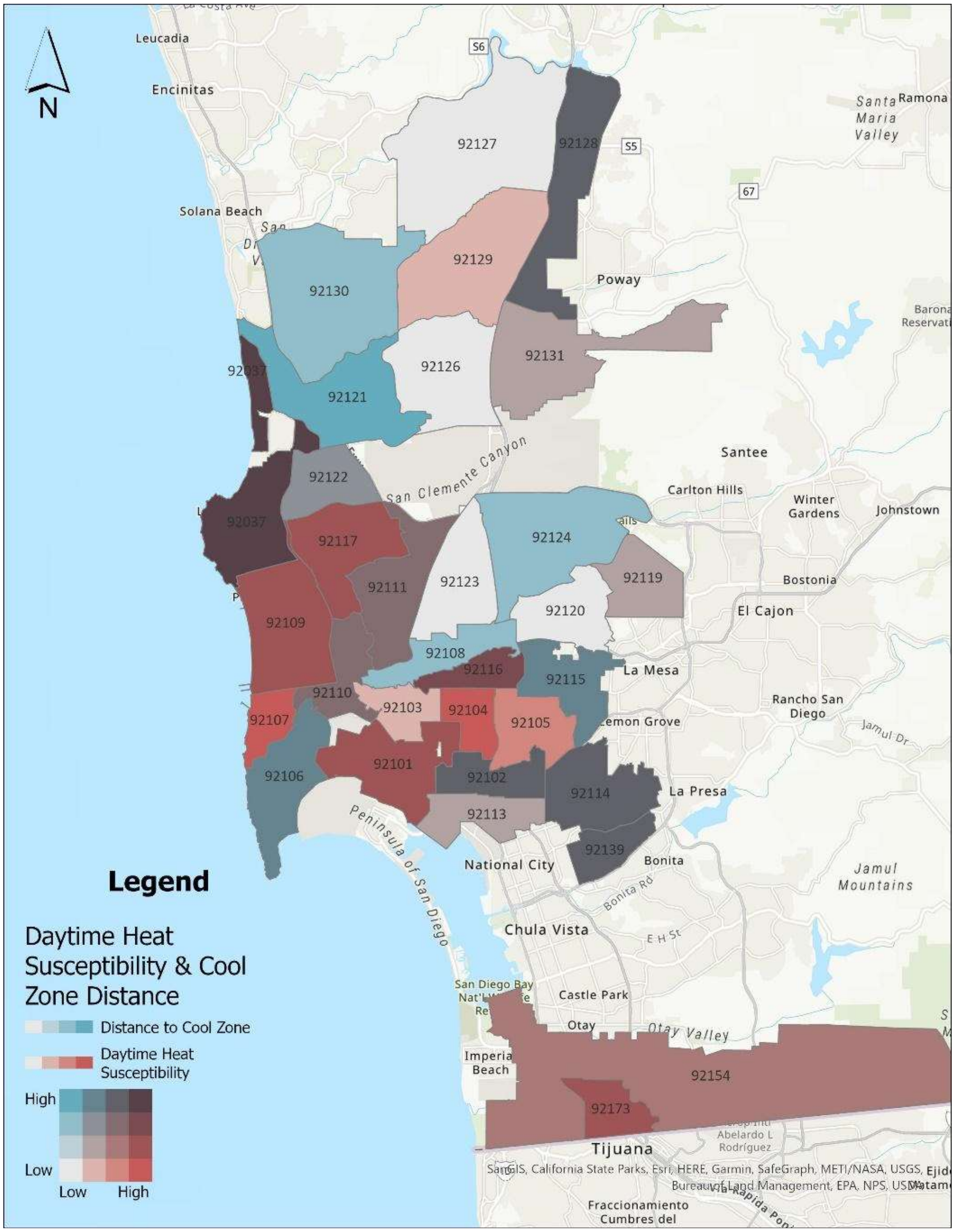


Figure 9: Daytime Heat Susceptibility and Cool Zone Distance Map.

Figure 10, Daytime Heat Susceptibility and Tree Canopy Coverage Map, was created utilizing the zip code ArcGIS layer and joining the daytime heat susceptibility and tree canopy data by zip code. Based on the map, zip codes **92101, 92109,** and **92173** (in order) are recommended to be prioritized due to low tree canopy coverage. There are other darker shaded zip codes that also could be prioritized secondarily based on high amount of area without tree canopy coverage.

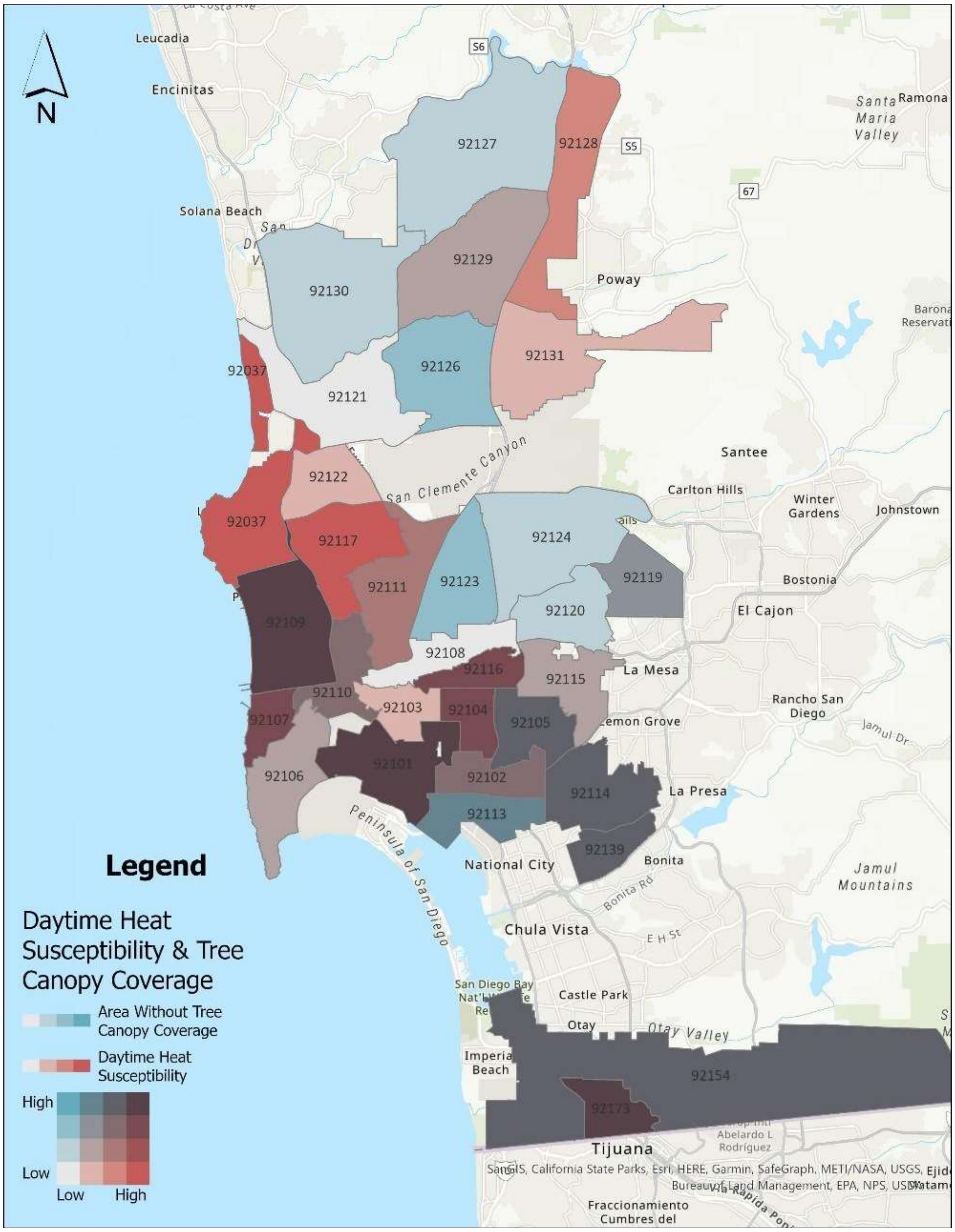


Figure 10: *Daytime Heat Susceptibility and Tree Canopy Coverage Map.*

Figure 11, Daytime Heat Susceptibility and Impervious Surface Coverage, was created utilizing the zip code ArcGIS layer and joining the daytime heat susceptibility and impervious surface data by zip code. Areas with high impervious surface coverage mean high amounts of non-permeable materials such as asphalt, which typically do a poor job of reflecting solar radiation and thus retain heat. Zip codes that are recommended for prioritization due to high amount of impervious surface coverage and high daytime heat susceptibility are **92101, 92104,** and **92107** (in order).

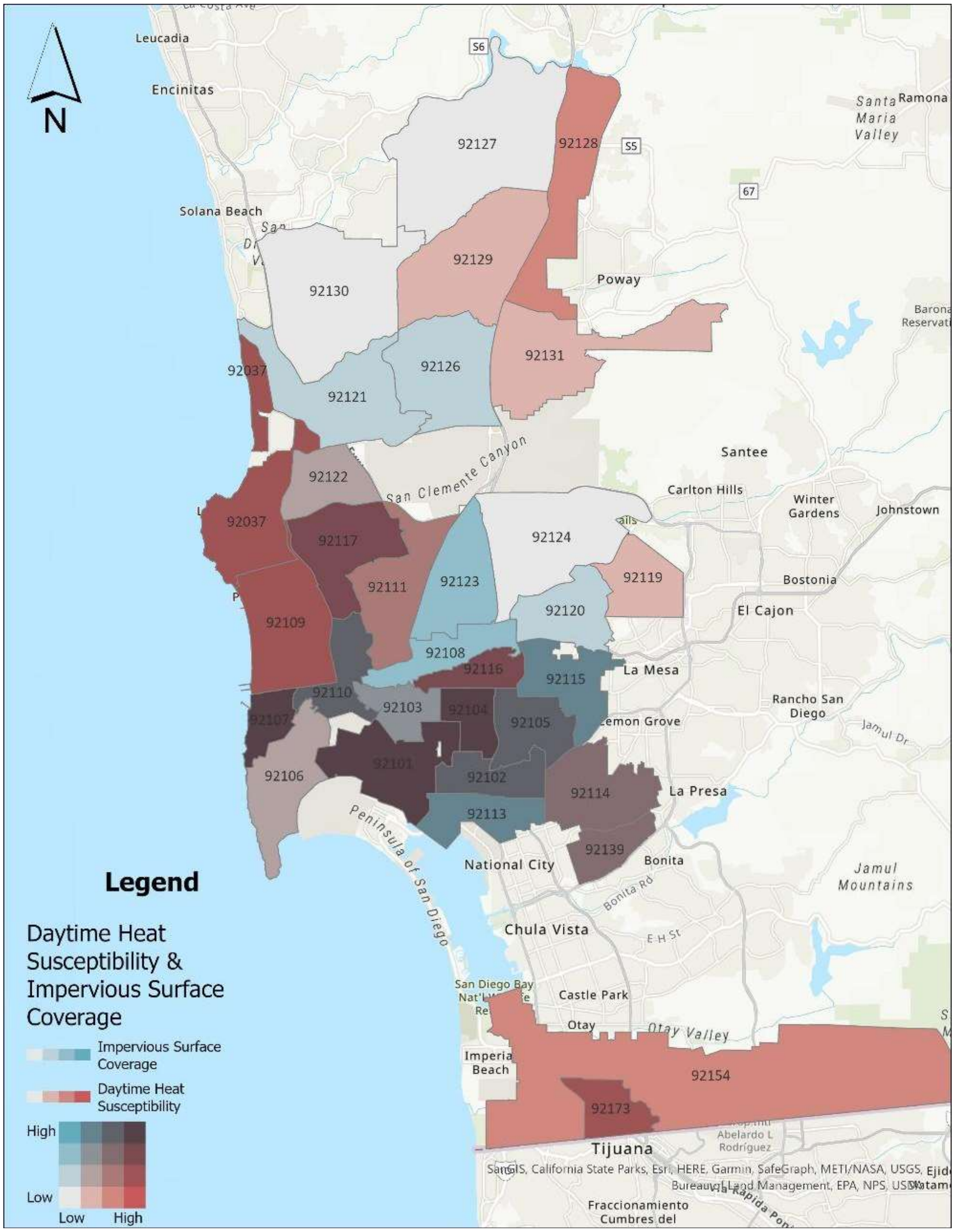


***Figure 11:** Daytime Heat Susceptibility and Impervious Surface Coverage*

Figure 12, Daytime Heat Susceptibility Combined Factors, was created utilizing the zip code ArcGIS layer and joining a file that contained the applicable Cool Zone distance, tree canopy cover, impervious surface coverage, and combined score data so that it could all be displayed when a zip code is selected. The map displays the combined scores for each zip code, ranked low to high. Zip codes **92101, 92102, 92110, 92114, 92116**, and **92129** all scored high for daytime heat susceptibility and all combined factors.

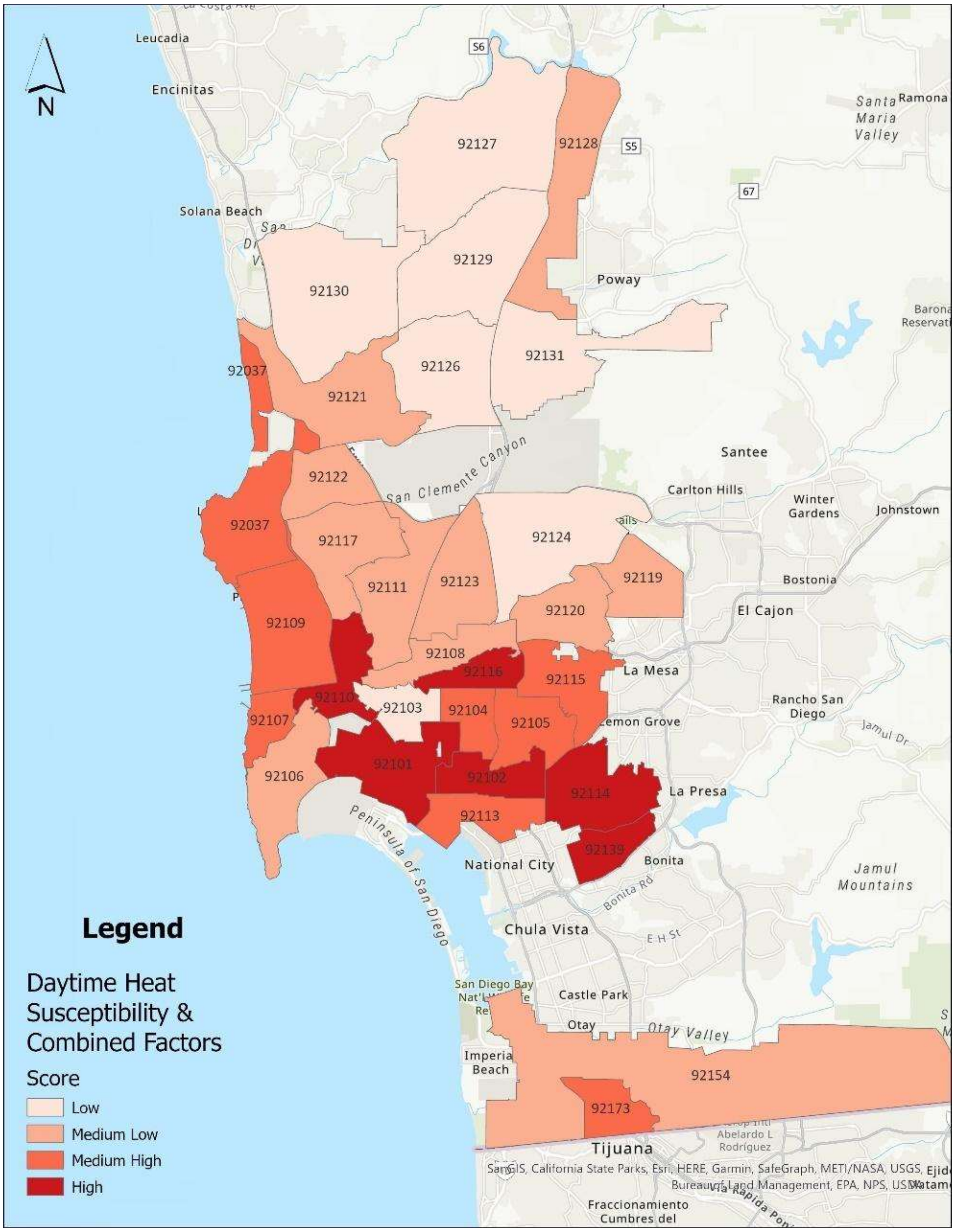


***Figure 12**: Daytime Heat Susceptibility Combined Factors.*

Figure 13, Nighttime Heat Susceptibility and Tree Canopy Coverage, was created utilizing the zip code ArcGIS layer and joining the nighttime heat susceptibility and tree canopy data by zip code. Zip code **92109** has both high daytime and nighttime heat susceptibility, and a high amount of area without tree canopy coverage. This zip code, as well as **92114**, are recommended to be prioritized for increased tree canopy coverage to help cool the areas. Tree canopy can be particularly helpful with reducing nighttime temperatures, which can have added benefits for areas with low prevalence of air conditioning use and due to lack of access to Cool Zones at night.

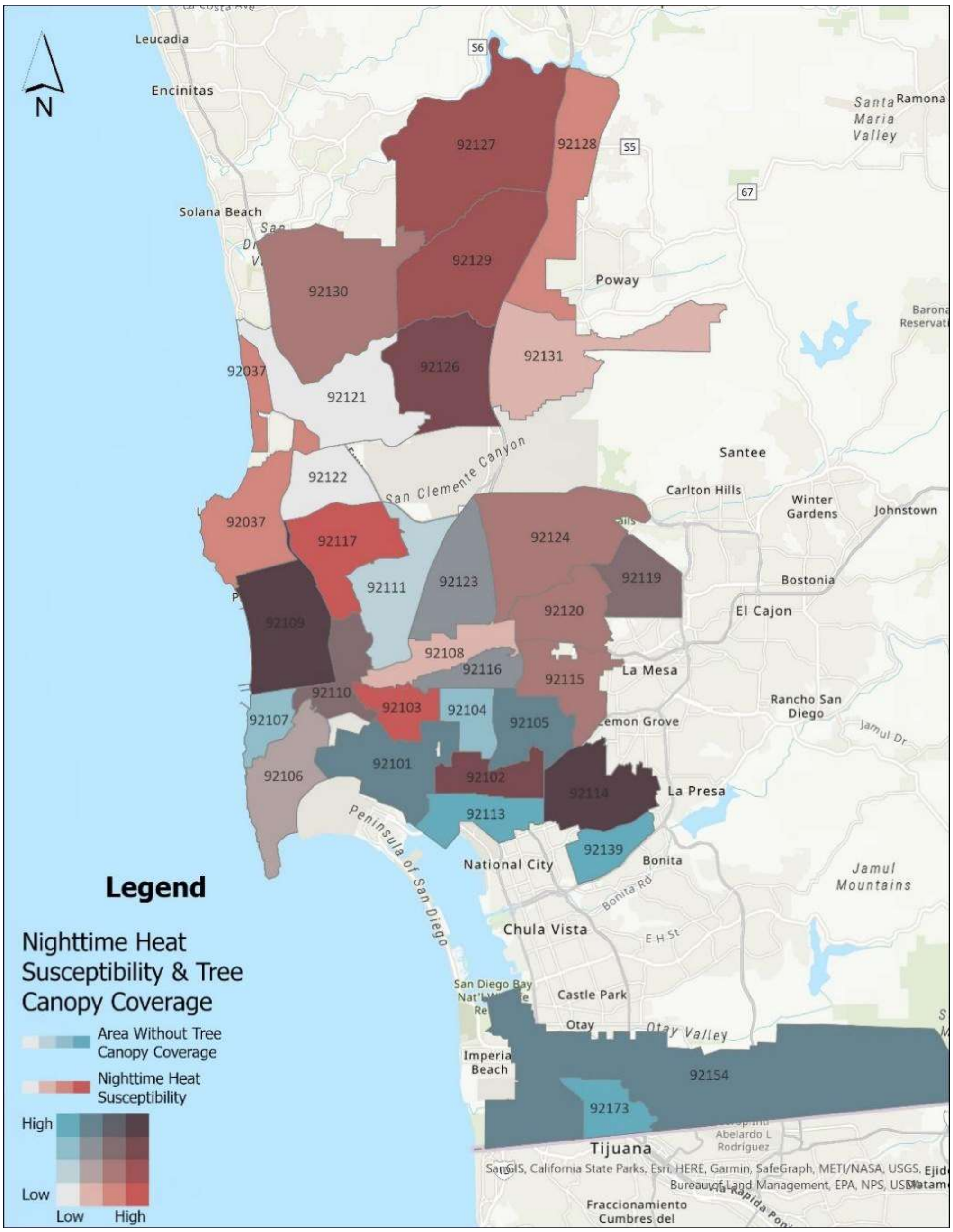


Figure 13: *Nighttime Heat Susceptibility and Tree Canopy Coverage.*

Figure 14, Nighttime Heat Susceptibility and Impervious Surface Coverage, was created utilizing the zip code ArcGIS layer and joining the nighttime heat susceptibility and impervious surface data by zip code. Zip code **92102** is recommended to be prioritized due to high nighttime heat susceptibility and high impervious surface cover, followed by **92103, 92114,** and **92117**, who all have high nighttime heat susceptibility and medium high impervious surface coverage.

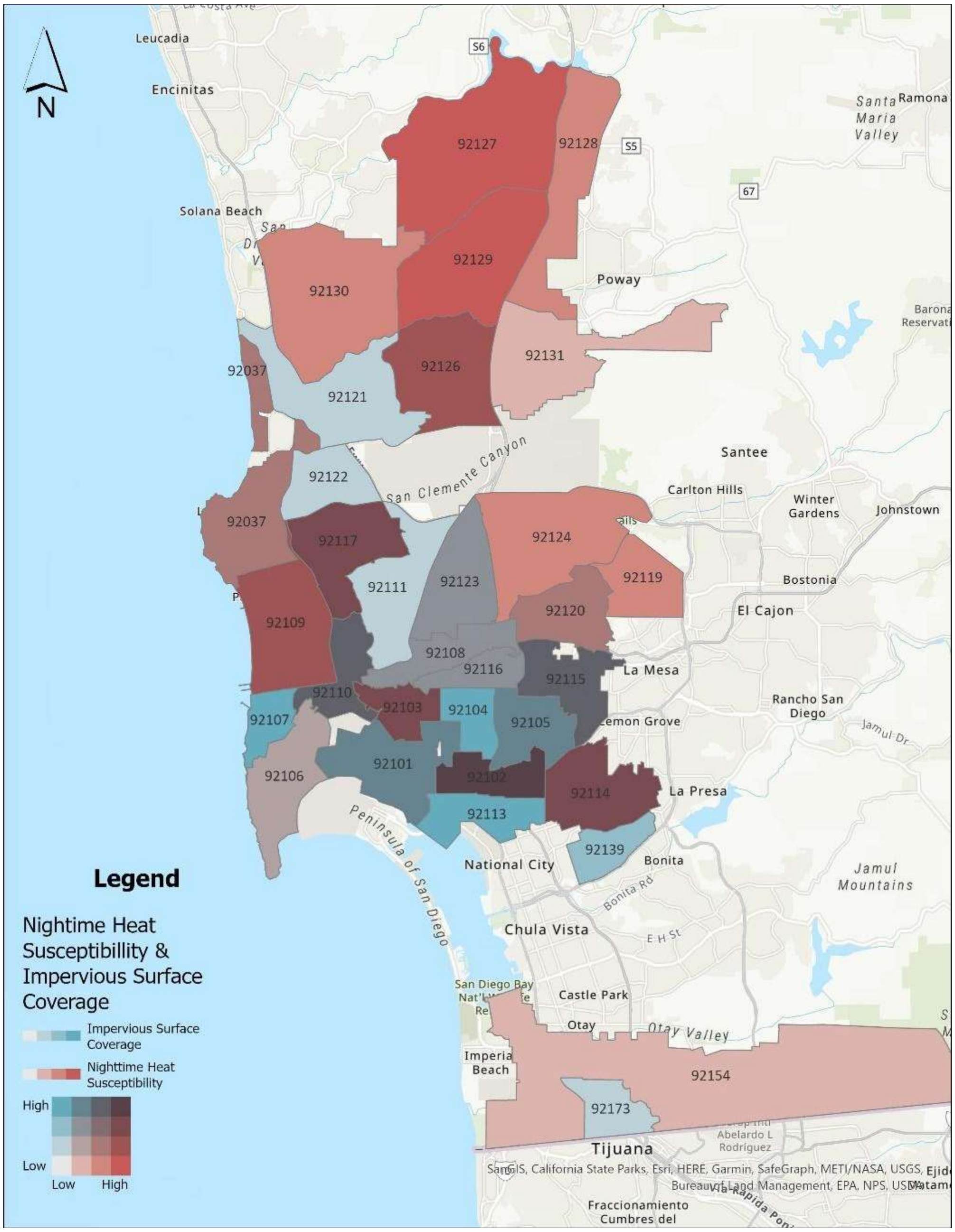


Figure 14: *Nighttime Heat Susceptibility and Impervious Surface Coverage.*

Figure 15, Nighttime Heat Susceptibility Combined Factors, was created utilizing the zip code ArcGIS layer and joining a file that contained the applicable tree canopy cover, impervious surface coverage, and combined score data so that it could all be displayed when a zip code is selected. The map displays the combined scores for each zip code, ranked low to high. The following zip codes scored high for both nighttime heat susceptibility and all combined factors: **92101, 92102, 92105, 92109, 92110,** and **92114** and are recommended to be prioritized for a combination of integrated strategy implementation.

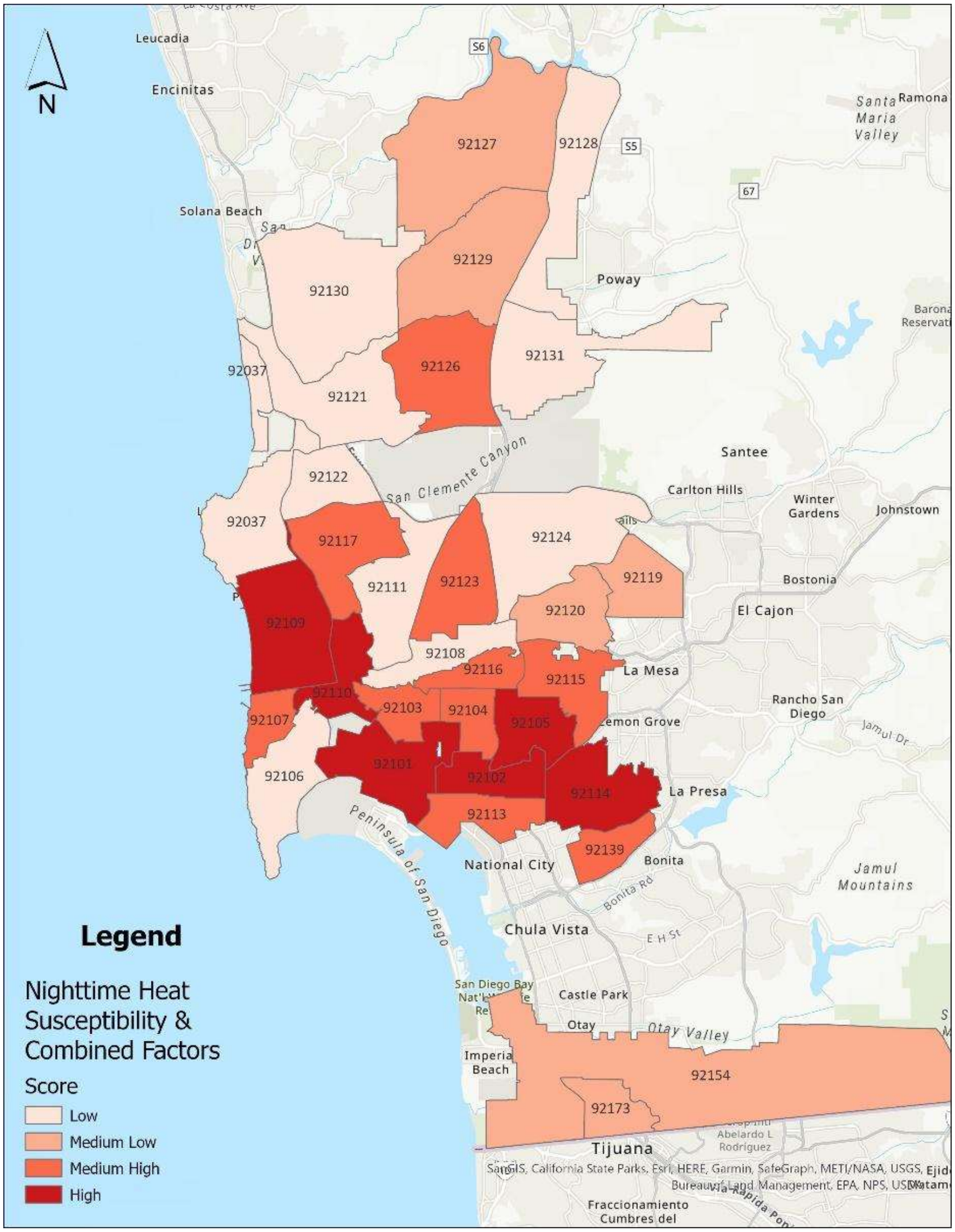


Figure 15: *Nighttime Heat Susceptibility Combined Factors.*

A StoryMap was created for the City of San Diego as a separate component of this project and is still being adapted based on feedback and intended audience. The StoryMap includes a brief overview of the project, description of scoring, interactive version of the ArcGIS maps contained in this report (users are able to click on zip codes to view the scores), discussion of applicable CRSD policies, and recommendations and other considerations for implementation.

Table 4 provides an overview of zip codes recommended for prioritization including Cool Zones, combined variable and daytime heat susceptibility, combined variable and nighttime heat susceptibility, combined factors and both day and nighttime heat susceptibility zip code overlap, and finally zip codes that ranked high for both day and night heat susceptibility and lack of tree canopy coverage and impervious surface coverage.

Recommended Zip Codes to be Prioritized					
Daytime Heat Susceptibility & Cool Zone	Combined Variable & Daytime Heat Susceptibility	Combined Variable & Nighttime Heat Susceptibility	Combined Variable Day & Night Susceptibility Overlap	Tree Canopy Day & Night Susceptibility Overlap	Impervious Surface Day & Night Susceptibility Overlap
*Figure 9	*Figure 12	*Figure 15			
92037	92101	92102	92101	92109	92101
92102	92102	92114	92102		92104
92139	92114	92101	92110		92107
92116	92139	92105	92114		
92128	92110	92109			
	92116	92110			

Table 4

Recommendations

Recommendations are based on map results and other best practices that have been discussed throughout the report. This section also includes information on how the maps can be used and updated in the future.

For the findings from the Daytime Heat Susceptibility and Cool Zone Distance map and taking into consideration the CRSD strategy of increasing the number of Cool Zones, **92037, 92102, 92114, 92139, 92116,** and **92128** are recommended to be prioritized for addition of a Cool Zone based on ranking either high for heat susceptibility and high distance to Cool Zone, or medium high heat susceptibility and high distance to Cool Zone. To carry out this strategy in the recommended zip codes, close collaboration with San Diego County is essential, as they maintain tracking over Cool Zones. Additionally, perhaps supplementary outreach to promote other initiatives from the County such as the *free electric fan program* in partnership with SDGE, that distributes free fans to those who rely on limited incomes (County of San Diego, n.d.) and *free rides to Cool Zones* (Brennan, 2021) for those in need could be conducted in these zip codes. An important component of this strategy's implementation will be outreach in the community to identify other ways to make Cool Zones more accessible and desirable places to visit during heat events.

For the top zip codes identified that have high heat susceptibility and low tree canopy, there are multiple points of integration that are recommended in order to make these findings most useful and relevant across other City plans and initiatives. Other relevant strategies and plans regarding increasing the urban tree canopy include but are not limited to:

- Urban Tree Canopy Assessment (by Community or Council District)
- Urban Forestry Program 5 Year Plan (2017)
- Free Tree San Diego Program

As these plans are updated, integrated, and implemented, zip codes that were identified in this project could be considered priority. Nighttime heat susceptibility zip codes should be a particular area of focus for implementation of expanded tree canopy due to increasing nighttime temperatures, which provides a lack of relief from the heat at night that many coastal residents without air conditioning rely on. Trees can help to combat the impacts of high nighttime temperatures and may be particularly beneficial in areas without air conditioning. Consistent with the recommendations in the Urban Forestry Five Year plan, native tree species should be favored when planting trees since they require less water which is favorable in San Diego's frequent drought conditions (City of San Diego, 2017). Native trees are better suited for the climate and will likely adapt better to rising heat than non-native trees, while contributing to and preserving biodiversity.

Impervious surfaces are common structures or surfaces such as pavement, sidewalks, roads, parking lots, and rooftops. Water cannot permeate these surfaces, and they may contribute to the urban heat island effect, causing high surface temperatures. Strategies in the CRSD plan that would contribute to reducing impervious surface coverage include implementation of cool pavement, cool roofs, green roofs, and urban greening programs. Specific plans such as the Street Tree Master Plan can be coordinated to prioritize zip code areas identified with high heat susceptibility and high impervious surface coverage. Additionally, the heat mapping that CAPA Strategies[2] performed for the City could be coordinated with this data to identify specific streets in these zip codes that would benefit from implementation of strategies such as cool pavement application and cool roofs. Best practices and information from the City of Los Angeles about their cool pavement application would be particularly useful to determine, at a finer scale, where to implement these strategies.

In order to facilitate cool roof adoption locally to meet CRSD goals, The City of San Diego plans on expanding conditions in Municipal Code Chapter 15, Article 5, Division 15 to include cool roof implementation (City of San Diego, 2021a). Some cities, including Pasadena, Louisville, and San Antonio, have cool roof incentives that provide residential homeowners and/or non-residential building owners with a rebate for reflective/cool roof materials applied. A cool roof incentive, in addition to other programs such the GoGreen Home program which allows

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[2] https://www.sandiego.gov/sites/default/files/heat_watch_san_diego_report.pdf

homeowners and renters to apply for financing options to help make energy efficient upgrades to their homes (*GoGreen Home Energy Financing*, 2022) should be considered in addition to changes to the municipal code, in order to help progress the adoption of cool roofs.

Zip codes with high combined scores for all factors with both daytime and nighttime heat susceptibility could be considered general focus areas. One potential way to approach strategies in these zip codes is to consider whole community impacts of heat. While these areas would likely benefit from the implementation of one or two of the previously discussed strategies, another idea is for planners to conduct pilot cooling projects in these neighborhoods. These types of projects would consist of a more holistic and integrated approach to heat, with extensive community outreach conducted and coordinated recommendations that integrate this feedback. Similar to Boston's neighborhood projects, these pilot programs could tracked over time and their performance could be evaluated in order to understand what combination of strategies were most effective to implement together. More information can be found in the *Boston Heat Resilience Plan*.

Overall Recommendations

- Increased **collaboration** across agencies and stakeholders (based on survey results regarding barriers to heat resilience planning).
- **Implementation and tracking** of effectiveness of these strategies over time (perhaps with assistance from or partnership with local universities/academic institutions)
- Update tree canopy and impervious surface maps with 2021 LiDAR data collected for the City when available for more accurate planning.
- Create a new map with **air conditioning** data once available to better understand where certain implementation strategies can help, particularly for nighttime heat susceptibility and those without air conditioning.

Considerations

- How could the forthcoming *Environmental Justice (EJ)* Element and results from the latest EJ Background Report be integrated within the context of these results?
- What mechanisms for *update and tracking* over time make sense and are feasible? Could a standing collaboration with academia help to advance these objectives?

Limitations

There were a few limitations to this project that can be updated and improved in the future as more resources become available. One important map to add in the future and component to examine would be prevalence/ use of air conditioning throughout the City. This information could give more context to zip codes that rank high for other factors that were examined and may change the recommended priority zip codes. Air conditioning data from the California 2019 Residential Appliance Saturation Study was not available in the required format needed for this project in time but is possible to be obtained and updated in the future.

An aerial LiDAR field data collection was completed for the City of San Diego in late 2021, and is still being processed by the data vendor for applicable uses. Once this data is ready, it can be used to update the tree canopy and impervious surface coverage maps to give a more accurate representation of zip codes that rank high for these factors. The current data for these factors was obtained from the Healthy Places Index and National Land Cover Database as utilized and described in Hale, 2020.

A final factor to consider, not necessarily as a limitation within the confines of this project, but one that will continue to impact future planning efforts if it is not improved is potential lack of coordination. There are numerous helpful maps and products already created and in development that can aid planners in planning for heat resilience, such as this project. What these don't provide is the necessary community outreach, collaboration between agencies, and integration with other related hazards that will be crucial to the future success of implementing these strategies and protecting residents and urban environments from heat impacts. Heat resilience planning is not as established as flood mitigation or other climate change hazards, despite being the most deadly. As this planning and hazard area develops, coordination across agencies that typically don't work together is crucial for success and establishing best practices.

CONCLUSIONS

In conclusion, these results provide recommendations for planners to identify and integrate priority areas for stated heat resilience strategies into their planning documents and processes. With best practices of coordination across stakeholders, community outreach, and strategy monitoring and adjustment over time, these strategies can help to reduce the impact of heat in the most susceptible zip codes in San Diego, while strengthening relationships between stakeholders including agencies and jurisdictions, and providing a host of co-benefits to the areas.

A central component of this implementation is equity. These strategies will not achieve the most effective outcomes in reducing susceptibility and providing heat relief if they are not accessible to and targeted for the most vulnerable populations in each community. The recommendations from this project represent a very small piece of the puzzle in the work that needs to be done going forward, and if climate change resilience efforts are not centered in equity, we will continue to leave integral members of our communities behind. Recommendations must be introduced to communities and stakeholders to understand how to implement them in the most equitable way while achieving desired outcomes of reducing urban heat.

Additional areas of proposed future research related to this topic is what, if any, climate change curriculum is included in planning programs. With the role of planners rapidly shifting as cities work to combat climate change impacts in their local communities, this background knowledge and foundation will be essential to protecting cities against the worse impacts of climate change. Another suggested area of research is to determine what the most effective combination of cooling strategies is for the San Diego region. Pilot projects, such as those suggested in this paper and conducted by the City of Boston, would be helpful to determine this, as well as implementation and monitoring programs over time.

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Appendix 1

Heat Adaptation Planning Survey

Start of Block: Default Question Block

Q1. **Respondent Name, City Department/Position (optional)**

____

Q2. **What assignments or projects are you involved with?**

____

Q3. **Are any of the following sources of data or information on extreme heat used in the project(s) that you previously or are currently working on?**

	Yes, currently in use	No, because it is not useful	No, because the information is not readily available to me	N/A
San Diego Heat Vulnerability Index/Map (NASA Develop)	○	○	○	○
Urban Heat Watch Program Maps (CAPA Strategies)	○	○	○	○
San Diego Climate Equity Index (Heat Vulnerability Map)	○	○	○	○
Land Surface Temperature Map	○	○	○	○
Vegetation or Tree Canopy Map	○	○	○	○

Q4. **How comfortable do you feel utilizing tools such as vulnerability indexes, ArcGIS maps, and other sources of data to make planning decisions?**

○ Extremely uncomfortable

○ Somewhat uncomfortable

○ Neither comfortable nor uncomfortable

○ Somewhat comfortable

○ Extremely comfortable

Q5. **Which heat adaptation strategies should be prioritized in San Diego? (rank strategies)**

_______ Increase urban tree canopy
_______ Install green roofs
_______ Install cool roofs
_______ Install cool pavement
_______ Use of cooling centers and/or resilience hubs
_______ Air conditioning programs/incentives
_______ Educational/community engagement programs
_______ Other

Q6. **To what degree do you consider the following as barriers to heat adaptation planning in San Diego or in the communities you work with?**

	Not a barrier	Slight barrier	Moderate barrier	Significant barrier	Don't know
Available data & tools on extreme heat risk	○	○	○	○	○
Knowledge of heat strategies	○	○	○	○	○
Funding	○	○	○	○	○
Time and Staff	○	○	○	○	○
Leadership	○	○	○	○	○
Public Support	○	○	○	○	○
Coordination between agencies and/or jurisdictions	○	○	○	○	○
Other hazards or issues are higher priority	○	○	○	○	○

Q7. **What other tools may be helpful in facilitating the implementation of heat adaptation strategies? (can select more than one)**

_______ Prioritization matrix for heat adaptation strategies
_______ Visualization tool about heat-related impacts in SD to identify communities most affected by heat-risk
_______ Visualization tool about the benefits of greening strategies in each neighborhood
_______ Tool to understand the ranking of heat events for each neighborhood (i.e. what type of heat event is most concerning in each location)
_______ Other

Q8. **If you would NOT like to be contacted following the survey to discuss these topics in more depth, please select NO.**

○ NO (please do not contact me)

○ YES (you may contact me)

End of Block: Default Question Block

Appendix 2

Hospitalization Data

We obtained all unscheduled hospitalizations data in California for the years 2004 – 2013 from the Office of Statewide Health Planning and Development (OSHPD). The following primary diagnoses were evaluated, as listed in the International Classification of Disease codes, 9th Revision, Clinical Modification (ICD-9): acute myocardial infarction (MI) (410), acute renal failure (584), cardiac dysrhythmias (427), cardiovascular disease (CVD) (390–459), dehydration/volume depletion (276.5), essential hypertension (401), heat illness (992), ischemic heart disease (410–414), ischemic stroke (433–436), and all respiratory diseases (460–519). These particular diseases were chosen because they have previously been linked to extreme temperatures (Bunker et al, 2016; Li et al., 2015, Sherbakov et al. 2018). For this analysis, all cardiovascular hospitalizations were grouped, leaving five hospitalization outcomes of interest. Data were aggregated into daily counts for each zip code, with data provided by the Census Bureau 2010 Census.

Meteorological Data and Heat Wave definition

Daily minimum and maximum temperature data were downloaded from a publicly available data set that collects data from approximately 20,000 National Ocean and Atmosphere Administration Cooperative Observer (NOAA COOP) stations across the US (Cal-Adapt 2015). Daily maximum and minimum temperatures (°C) was derived from 1/16° (~6 km) gridded observed data from this data set for all of California (Livneh et al. 2015). Population-weighted centroids for each ZCTA were linked to the nearest temperature measurements. A day was defined as a heat wave (HW) day if the daily maximum temperature was greater than or equal to the 95th percentile of the distribution of maximum temperatures during the warm season (May-September) for each zip code. We considered 18 definitions of HW, these include maximum and minimum for each day. We considered 1,2-, and 3-day HW as well as considering percentiles 95%, 97.5%, 99% for minimum and maximum temperatures and 1%, 2.5%, and 5% for difference in temperature.