SWELTERING CITIES

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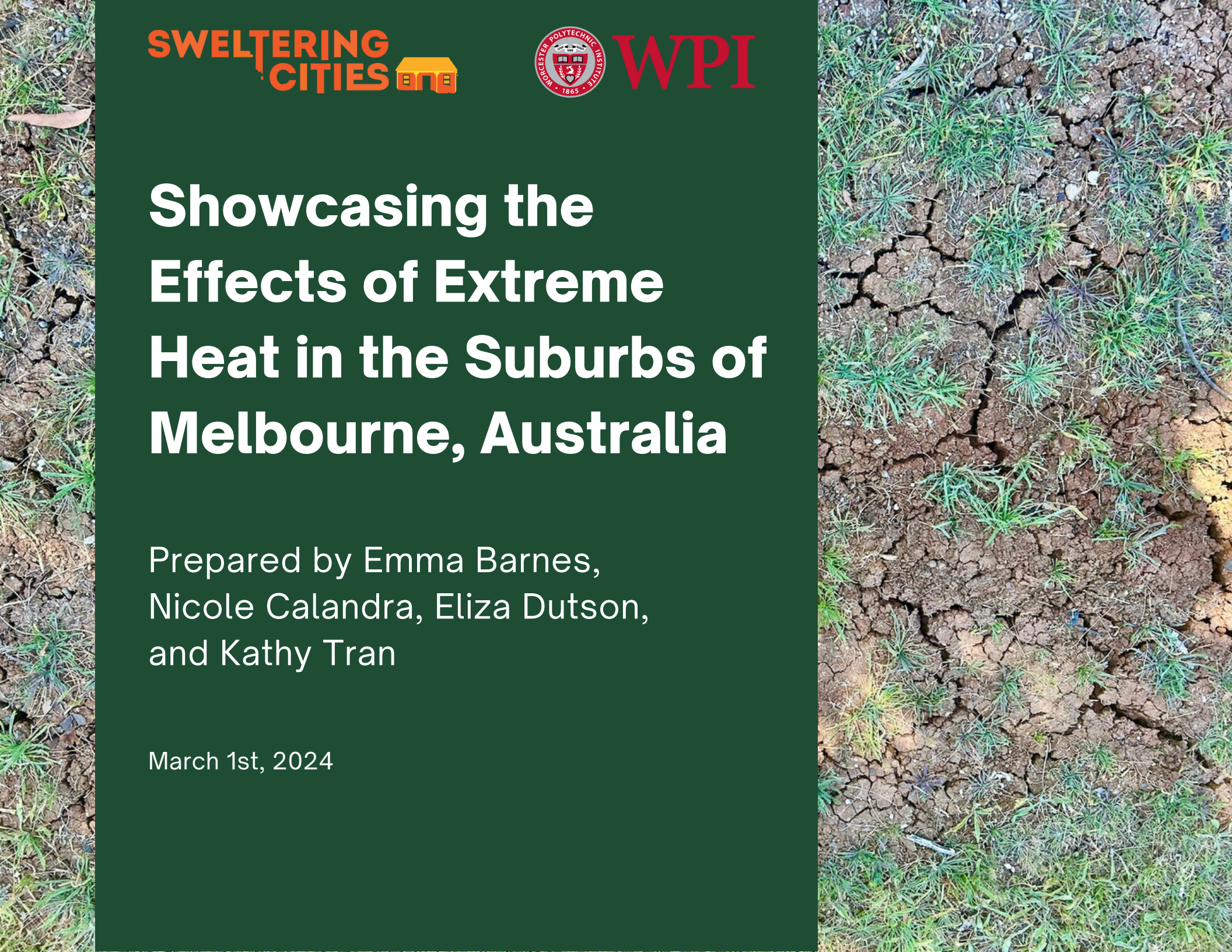
Showcasing the Effects of Extreme Heat in the Suburbs of Melbourne, Australia

Prepared by Emma Barnes, Nicole Calandra, Eliza Dutson, and Kathy Tran

March 1st, 2024



Showcasing the Effects of Extreme Heat in the Suburbs of Melbourne, Australia

An Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the degree of Bachelor of Science.

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Abstract

Our report shares the stories of how four suburbs of Melbourne experience extreme heat. To show dangerous surface and air temperatures, we collected data from the suburbs on the warmest days. We conducted twenty six interviews with community members and leaders to hear about their experiences in the heat. We combined these findings into an ArcGIS StoryMap to fabricate a story that spreads advocacy and awareness around the effects of extreme heat in Melbourne.

Authorship

EMMA BARNES
was the primary researcher and author of the abstract, executive summary, introduction, “Impact of Rising Temperatures,” “Populations Vulnerable to Extreme Heat,” and “Urban Heat Islands” in the background, Methods 2 and 3, the demographics sections of the results, the deliverables section, and the conclusion. Emma was also a primary editor of all sections of the report. She helped organize data for each of the suburbs and pulled analysis statements used to develop the StoryMap deliverable. Emma was essential to the StoryMap drafting and editing process, and was a primary author of the introduction and Dandenong section.

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was the primary researcher and author of the introduction, “Populations Vulnerable to Extreme Heat” and “Vegetation as a Cooling Strategy” in the background, Methods 2 and 3, and the data tables and interviews in the results. Nicole was also a primary editor of all sections of the report. She contributed to the background research of each suburb and wrote stories for the Wyndham Vale, St. Albans, and Broadmeadows part of the StoryMap. Nicole was a primary content creator of the StoryMap–importing maps, designing interactive features, and editing videos and audio recordings. Nicole was a primary author of the Broadmeadows and St. Albans section of the StoryMap.

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was a primary editor for all sections of the report. She was a primary researcher and author for the “Impact of Rising Temperatures,” “Urban Heat Islands,” “Vegetation as a Cooling Strategy,” Appendix C, “The Power of Integrative Storytelling”, Method 1, and “Findings”. Kathy worked closely in the interview process by helping to conduct interviews, write detailed notes, and pull integral quotes. She helped organize data for each of the suburbs and pulled analysis statements used to develop the StoryMap deliverable. She is also the author of the Wyndham Vale section and part of the St. Albans section of the StoryMap. Kathy was a primary content creator of the StoryMap.

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Executive Summary

Background

Climate change is a pressing global issue, with Australia experiencing notable consequences. Heatwaves are the highest cause of death by climate disaster across the country (Coates et al., 2014). In Victoria, the city of Melbourne especially grapples with the effects every summer. The city's landscape exacerbates the problem, as its infrastructure creates urban heat islands (UHIs) that can be up to 10°C hotter than surrounding areas. Common building materials such as concrete, brick, and tiles are known to have higher heat retention and contribute greatly to the UHI effect (Reardon et al., 2020). With only 15.3% urban canopy coverage across Greater Melbourne, certain locations, such as bus stops and parking lots, become vulnerable hotspots. In contrast, areas with more greenery demonstrate the ability to mitigate rising temperatures.

Heat waves are a deadly climate disaster, but lack visual cues. Many residents are unaware of the risks posed by this ‘silent killer.’ Recent research conducted by the Australian Red Cross found that only 10% of Australians are taking steps to actively prepare for heatwaves (May, 2023).

Our Approach

To address the lack of awareness surrounding the effects of heatwaves in Melbourne, we told stories using temperature data and first hand experiences of community members to help Sweltering Cities spread awareness about how extreme heat affects Melbourne’s communities. We utilized integrative storytelling through the inclusion of engaging forms of media, such as videos, photos, and graphs to contextualize data emotionally and realistically, helping to spread awareness. In order to tell the stories of Melbourne’s communities, we chose four suburbs to focus on based on their socioeconomic statuses and/or tree canopy cover: Broadmeadows, Dandenong, St. Albans, and Wyndham Vale. Figure 1 shows the locations of these suburbs.

Figure 1: Locations of St. Albans, Broadmeadows, Wyndham Vale, and Dandenong in the city of Melbourne.

Our first method was to collect temperature data to analyze the heat intensity of community spaces in each suburb. To do so, we determined that areas vulnerable to extreme heat in each suburb included parks/green spaces, playgrounds, bus stops, parking lots, and benches. At each area, we recorded the date and time that the measurements were taken, as well as their exact location coordinates. In addition, we recorded the weather app

temperature and conditions at the time of collection. We took note of the demographics and level of activity, as well as context photos and videos, to analyze how temperatures affected the use of the space.

Our second method was to conduct interviews to understand how extreme heat impacts community members in each neighborhood. We identified four key groups of people to interview: general community members, community leaders (who hold a local government or nonprofit organizational position to help the community), medical professionals, and outside workers. With the media gathered from the interviews, we took notes from each voice or video recording. The notes were structured to identify key quotes and concepts, and to separate the different answers gathered from each question that was asked.

Our final method was to combine our findings into an ArcGIS StoryMap to showcase the dangers of extreme heat. We incorporated visual data collected in the field, including interviews, weather data, descriptive comments, videos, small scale case studies, and thermographic images. These features allow our data to be well visualized (Scott et al., 2016). We displayed our findings using ArcGIS StoryMap technology and posted a link to the Sweltering Cities website for it to be shared publicly.

Project Outcomes

We begin with general findings on impact of extreme heat across Melbourne. Interviews conducted with community members in Melbourne highlight the dangers of the city's intense heat, especially due to high UV levels. Shane, a security guard from Melbourne, says, “In Melbourne the UV is really really high in the summer, so I have to be really mindful and careful.” He then describes his summer experience in Malaysia where the temperature is often 33°C or higher, but he does not worry about getting sunburned. Workers face significant risks due to extreme temperatures, with many cases of heat-related deaths reported among indoor and outdoor workers. Zarah, a climate organizer for the United Workers Union, speaks to this danger. She says, “People can risk their lives, and unfortunately lose their lives, because of violations of health and safety.” A general practitioner, Dr. Jenny Huang, emphasizes the impact on workforce concentration, productivity, and mental health. Fiona, a women’s health officer working with migrant communities, discusses challenges in accessing emergency services due to language barriers, particularly for manual laborers facing heat-related illnesses.

Surface and air temperature data reveal how susceptible materials like wood and rubber are to propagating heat. They consistently exceeded 60°C on a day that was only recorded to be 29°C. Surface temperatures greater than 60°C are considered unsafe and can cause first-degree burns within short lengths of contact (Safety Action, 2019). These temperatures indicate that the heat intensity of playground

structures poses risk of burns to children. Dark surfaces contribute to the urban heat island effect, leading to higher temperatures than reported weather data. Canopy coverage was found to consistently reduce surface temperatures by over 10°C. Although both green and artificial canopies provide cooling areas, greenery absorbs heat whereas non-living materials propagate more heat above the canopy. For example, the difference between surface temperatures of artificial grass and real grass were up to 25°C. These overall findings were present in every suburb.

Broadmeadows

In Broadmeadows, transportation, working, and living conditions reveal the dangers of extreme heat. Waiting at bus stops and train stations for an unexpected period of time can be brutal during times of extreme heat. At the Broadmeadows train station shown in Figure 2, there is limited seating in the shade. On this 28°C day, the surface temperature of this bench was 47.7°C. Additionally, the recorded air temperature was 7°C higher than what was projected on Apple's weather app. This is partially due to the heat that radiates off of the concrete and metal surfaces of the train station.

Terina is an employee at the Common Bean Cafe, who shares the struggles of workers that are exposed to extreme heat, as she works in an outdoor cafe built from a shipping container. She shares, **"We're so subject to the elements here… actually inside the container is usually about 4-5°C hotter than it is outside. Mainly because there's not a lot of airflow and because we've got stoves and ovens in there."** We also interviewed a senior citizen who has been living in public housing for over 30 years, and air conditioning is only available downstairs. She stated that she is unable to sleep upstairs because it is too hot. This is a strong indicator that housing arrangements are insufficient against climate conditions and vulnerable communities that rely on public housing are affected.

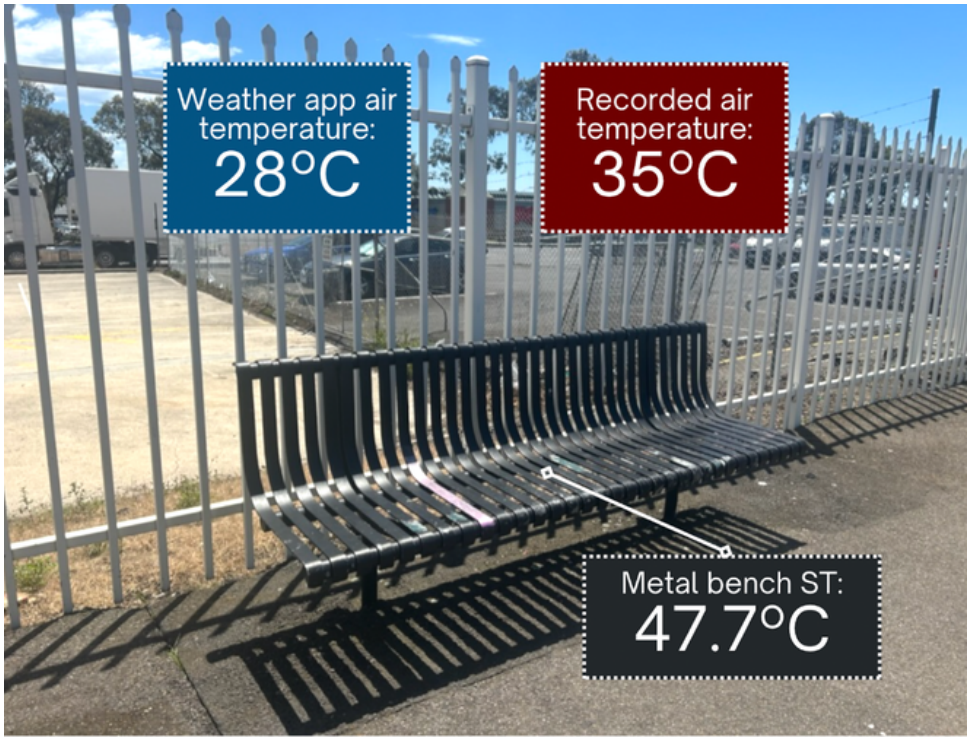

Figure 2: Image of Broadmeadows Train Station with the weather app temperature, recorded air temperature, and surface temperature of the bench.

Dandenong

In Dandenong, the city council is taking the lead in policy and public awareness to make their community safer. Ideally, their action on a local governmental level will influence and encourage state regulations. Dandenong City Council has been implementing positive change, such as increasing canopy coverage. We visited two playgrounds in Dandenong, one with canopy coverage and one without. The constructed canopy of the Red Gum Rest Playground in Dandenong reduced surface temperatures, making it safer to use on hot days. Members of the emergency services and sustainability sectors of Dandenong City Council shared many of their own policies and plans, including their heat action plan. This plan, which is published in a section on the city's website, gives guidance on who is at risk, how to reduce the impact of heat, and the signs of heat exhaustion. They also have this information printed on pamphlets for residents who do not have internet access and on translated pamphlets for residents who do not speak English. One of their emergency management leaders shared, **"We're all trying to make a significant difference, but we are not waiting on the state government or even the federal government to get on with it, we are mobilizing ourselves."** Dandenong City Council has been taking steps toward making their communities safer.

St. Albans

Children and other demographics are especially vulnerable to extreme heat. In St. Albans, we analyzed various surface temperatures of a playground. On a 37°C day, wood and rubber materials at Silvan Court Playground consistently reached temperatures over 60°C, which is considered unsafe for contact. In addition, through a Google Earth analysis, we found that none of the 18 public playgrounds in the suburb had constructed canopy covers. These scorching materials, in conjunction with the lack of shade, render these playgrounds unsafe and essentially unusable. Dr. Jennifer Huang, a general practitioner, talks about the effects of heat—particularly regarding people with pre-existing health conditions—saying, **"As years go on with climate change, I do think unless we prevent the planet from warming up further, there's large swaths of different conditions that will be exacerbated and worsen on hot days."** Pre-existing medical issues can impair the ability to thermoregulate when triggered or worsened by heat. The demographic that suffers most commonly from pre-existing conditions is the elderly. Women experiencing menopause can also be more prone to heat stress, since menopause disrupts thermoregulation. While each of these suburbs have a higher migrant population than the Greater Melbourne area, St. Albans has the highest at 67.5% of residents born outside of Australia. It is especially important to understand how the heat impacts migrant communities. From working with migrant mothers, Fiona understands the challenges and struggles that result from moving to an unfamiliar country and navigating language barriers. She shares,

“For a lot of the women being not able to speak english—being unfamiliar and anxious about calling emergency services when they know that the operator is going to speak English, a lot of them were not aware that there would be an interpreter put on the phone as soon as they’ve identified what language—and that was a barrier for them—in terms of emergency services.” Children, migrant communities, and the elderly are a few key examples of populations that are more vulnerable to extreme heat.

Wyndham Vale

The packed houses, dark roofs, artificial lawns, and lack of trees of Wyndham Vale's new development worsens the urban heat island effect. Measuring the temperature difference between white-painted pavement and black pavement on a 29°C sunny day, we found that the black pavement was 15°C hotter than the white pavement. This demonstrates that darker materials retain more heat than lighter materials. Since dark roofs cover the majority of each plot of land, the heat radiates off of the roofs, contributing to the urban heat island effect. The yards lacked trees and were made of artificial grass. On a 30°C sunny day, we found that artificial grass was over 27°C hotter than real grass. This is because plants are able to absorb heat and even cool their surroundings via evapotranspiration. June, a 23 year long resident of the suburb, shared her thoughts: **“They’re doing it badly, they’re putting in so many houses, so close together. The streets are very very narrow. So, you can’t always plant a tree that's going to have canopy or give shade in the future. And also because the yards are very small, people are putting in false grass which is virtually plastic, which again heats up and gets really really hot. So then you don’t even get the water to go through it properly and into the soil. It's not a pretty suburb at the moment.”** All of these aspects combined contribute to Wyndham Vale’s urban heat island effect.

Melbourne's suburbs are dealing with the complex impacts of extreme heat, which we aimed to display using our StoryMap. We created this to spread awareness of extreme heat and demand community engagement and policy enhancements. The experiences and efforts outlined across these suburbs highlight the need to tackle the increasing problems caused by extreme heat. With further research and advocacy, the issue of extreme heat can be mitigated before it progresses beyond repair.

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Introduction

Climate change is a global issue, bringing shrinking glaciers, rising sea levels, hotter temperatures, more frequent heat waves, droughts, and wildfires around the world. Australia is particularly susceptible to the impacts of climate change; the average temperature rise resulting from climate change since 1911 is 1.4℃ in Australia, compared to 1.1℃ globally (Australian Museum, 2021).

Melbourne is located in the state of Victoria on the southeastern tip of Australia. Compared to all other states in Australia, Victoria is seen to have the highest number of deaths due to heat related incidents, with 742 recorded from 1907-2010 (Coates et al., 2014). Communities local to Melbourne feel the effects of these rising temperatures firsthand. Currently, Melbourne averages 11 days a year above 35℃ (equivalent to 95℉), and by the year 2050, this number is expected to rise to 16 days (City of Melbourne, n.d.). This increase will continue to cause detrimental effects to residents' wellbeing.

The city contains many urban heat islands, which are concentrations of heat that can be up to 10℃ hotter than surrounding neighborhoods. Some locations are more susceptible to being extremely hot, such as uncovered bus stops, playgrounds, and asphalt parking lots. In contrast, areas with more tree cover and green roofs have been shown to reduce temperatures (Saber et al., 2012). Data collected by the Victoria State Government from 2018 found that across Greater Melbourne, there is only 15.3% urban canopy coverage (Department of Transport and Planning, n.d.). In some suburbs, canopy coverage is much lower than this. Along with a lack of canopy coverage, there is a lack of preparedness from community members regarding extreme heat. Recent research conducted by the Australian Red Cross found that only 10% of Australians are taking steps to actively prepare for heatwaves (May, 2023). Heat waves are a deadly climate disaster, but lack visual cues. Many residents are unaware of the risks posed by this 'silent killer' (May, 2023).

Sweltering Cities is a not-for-profit advocacy group that recognizes this lack of preparedness and awareness, and calls for justice in communities affected by extreme heat. The group was founded in Sydney in 2020 and has expanded to work in Melbourne and Brisbane as well. Sweltering Cities collaborates closely with urban Australian communities to bring awareness to the devastating effects caused by heat waves, especially in poorer areas. Their mission is to amplify community members' stories and use these stories to advocate for policy changes regarding extreme heat. With these efforts, Sweltering Cities aims to cultivate more liveable, equitable, and sustainable cities (Bacon et al., 2022).

Sweltering Cities has engaged our research team to highlight and share the imminent danger of rising temperatures in four suburbs of Melbourne: Broadmeadows, Dandenong, Wyndham Vale, and St. Albans. These suburbs were chosen in collaboration with Sweltering Cities due to their low economic status and/or low canopy coverage. The goal of our project is to tell stories using temperature data

and first hand experiences to help Sweltering Cities spread awareness about how extreme heat affects Melbourne's communities. To accomplish this, we (i) collected temperature data to analyze the heat intensity of community spaces in Broadmeadows, Dandenong, Wyndham Vale, and St. Albans, (ii) conducted interviews to understand how extreme heat impacts community members in each neighborhood, and (iii) combined our findings into an ArcGIS StoryMap to showcase the dangers of extreme heat.

Background

In this chapter we discuss heat waves and extreme temperatures in Australia, along with the detrimental effects they have on communities. We investigate urban heat islands and their presence in Melbourne. We explain the concepts of thermography and review heat-related policies that are in place in Australia and other regions. Finally, we introduce StoryMaps and demonstrate how they can be used to advocate for environmental inequalities.

Impact of Rising Temperatures in Australia

Melbourne feels the effects of climate change every year. As the Earth experiences rising temperatures and shifting weather patterns, Melbourne experiences discernible effects that create an urgency for resiliency planning (Zhang et al., 2018). The effects of climate change threaten the viability of current infrastructure against natural weather conditions. The most notable of Melbourne's extreme climate trends include unpredictable rainfall patterns and extreme heat waves (Yilmaz et al., 2014). Heat waves in Australia have continually posed issues for communities. Heat wave occurrences are increasing and are predicted to continue (Victoria Department of Health, 2023). Temperatures are seen to consistently increase by decade, but not always year to year, resulting in an overall positive trend in temperature (Bureau of Meteorology, 2023).

As temperatures continue to climb, more than half of Australians are expected to be affected by heat waves this upcoming summer, 2024, compared to only a quarter just five years ago (May, 2023). While there are a myriad of issues caused by heat waves, the most concerning is the fact that the heat-related death toll is on the rise. A study regarding deaths due to heat wave conditions found that over a 17-year period, from 2001-2018, over 400 people died due to conditions induced by extreme heat in Australia (Coates, 2022). In the past century, heat waves were the cause of over 50% of deaths from natural hazards in Australia, and they are the leading cause of death by climate-related disaster in Australia (Coates et al., 2014). Research has determined that most of the heat wave fatalities occur in the southern region of Australia, including the state of Victoria, as shown in Figure 3 (Coates et al., 2014).

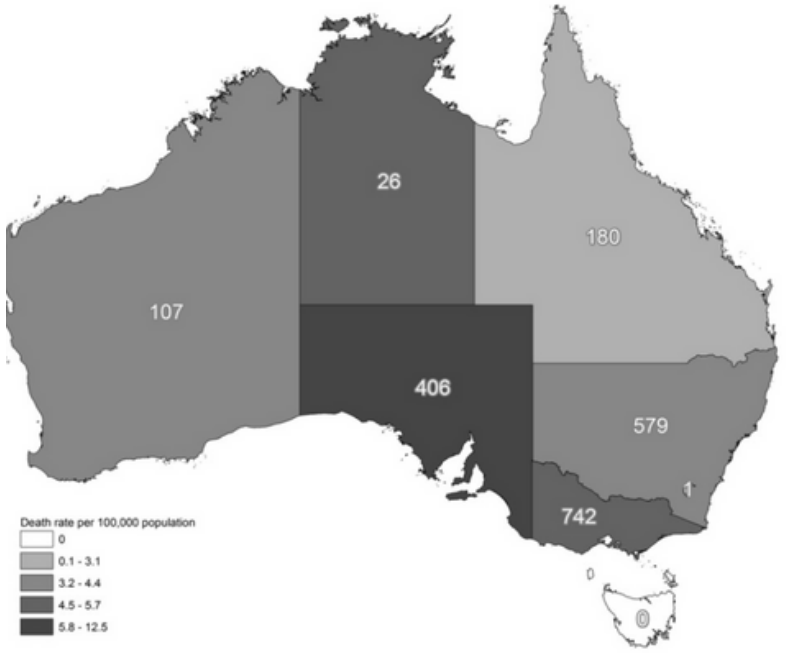

Figure 3: This map of Australia shows the number of heat related deaths that occurred in each state from 1907-2010 (Coates et al., 2014).

Extreme heat also has an impact on quality of life. In 2014, a retrospective study done by the Victoria Department of Health showed that during heatwaves, there is an increase in Ambulance Victoria responses, heat related presentations, and health services responses, putting additional stress on health care workers and emergency responders (Victoria Department of Health, 2024). Heatwaves also place the electrical grid under high stress, which can lead to blackouts (Energy Networks Australia, 2019). With blackouts comes a lack of air conditioning, refrigeration, and running water, all of which negatively impact residents' quality of life.

In addition to its residents, Australia's natural environment suffers from the effects of increasing temperatures. Severe heat depletes soil moisture levels, amplifying the effects of heat waves. At the beginning of 2009, heat waves and dry environmental conditions led to the most devastating bushfires in Australian history, known as the "Black Saturday" fires. The aftermath of this extreme heatwave resulted in numerous records set for hottest daytime and nighttime temperatures as well as the duration of the heat wave (Perkins-Kirkpatrick et al., 2016).

Figure 4 shows the predicted monthly data for the maximum heat index in Melbourne, Australia. By 2065, Melbourne's expected maximum heat index is predicted to reach 42.6°C (Arup, 2023).

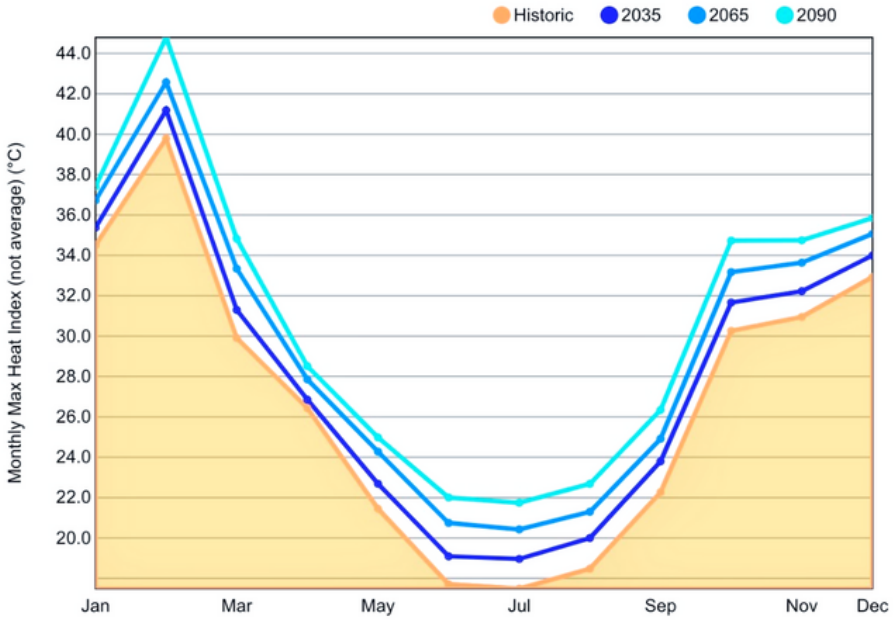

Figure 4: Monthly Projections of Max Heat Index in Melbourne, Australia, with an emission RCP of 8.5 and a warming percentile of 50% (Arup, 2023).

Populations Vulnerable to Extreme Heat

Different demographics experience extreme heat differently. In particular, the elderly and young children are most vulnerable to extreme heat conditions (City of Melbourne, n.d.). The elderly are heavily affected by extreme temperatures because they often have pre-existing medical issues that make thermoregulation difficult which can be triggered or worsened (Dept of Human Services, 2011) (Hughes et al., 2016). A study done in Germany found that deaths due to chronic lower respiratory diseases (CLRD), such as bronchitis and asthma, increased during

periods of extreme heat (Mücke & Litvinovitch, 2020). Children are more likely to suffer from respiratory disease, renal disease, electrolyte imbalance, and fever during heat waves (Xu et al., 2014). Children also depend on their caretakers to keep them hydrated and in a safe environment. For example, paramedics in Victoria were called to rescue 1,433 children from locked cars in just one year (Ambulance Victoria, 2015).

Outdoor workers are also more vulnerable to extreme temperatures. Outside workers, as well as inside workers with inadequate cooling, have a greater risk of injury and illness in extreme temperatures (Varghese et al., 2019). There is a significant rise in workers' compensation claims when temperatures exceed 40.6 ℃ (105 ℉) (Varghese et al., 2019). In a study done by the University of Adelaide, occupational injuries and illness (OI) were found to increase with higher temperatures and geographical variations. Part of this study focuses on Melbourne, where urbanized coastal areas were found to be more at risk with moderate and extreme temperatures (Fatima et al., 2023). Risk maps of the greater Melbourne area from this study can be seen in Figure 5. In this map, OI risk is defined as the estimated percentage of outdoor workers that will suffer from OI in both moderate and extreme temperatures. As these high temperatures become more frequent, the danger to workers in such conditions increases.

Poor communities are also disproportionately affected by extreme heat. People who live in poverty account for about 19% of Melbourne's population and are more vulnerable to heat waves (City of Melbourne, n.d.). The lack of money to pay for air conditioning or adequate food and water increases risks from extreme heat (McNeill & Drew, 2022). Poor communities also do not have air conditioners in classrooms, which impedes students' ability to learn (McNeill & Drew, 2022).

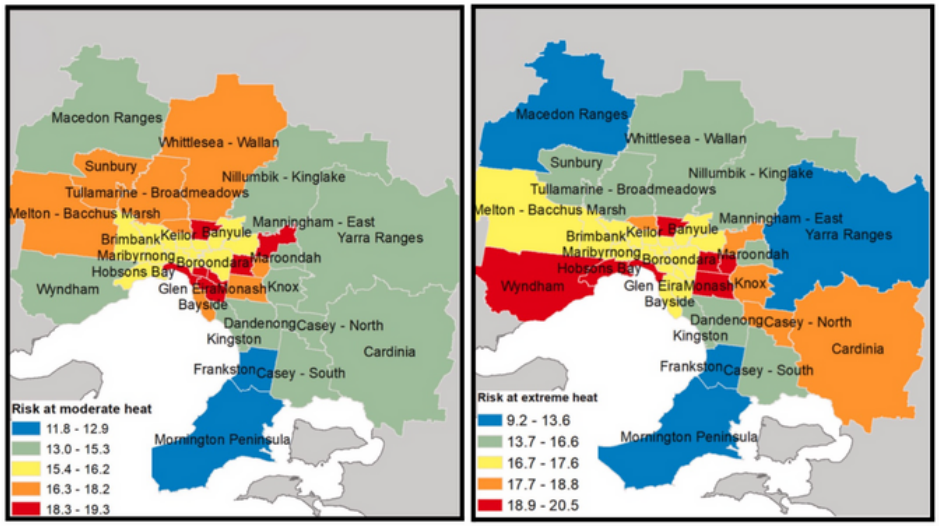

Figure 5: OI Risk in Melbourne, Australia at moderate heat (left) and extreme heat (right). The numbers in the legend indicate the percentage of outdoor workers that will suffer from OI. Note. Adapted from Fatima et al., 2023.

Urban Heat Islands

Highly urbanized areas in cities often have higher temperatures than surrounding neighborhoods, a phenomenon defined as the urban heat island (UHI) effect. UHIs are caused by many factors, some controllable and others uncontrollable. Controllable factors that affect UHI severity include amount of green areas, building materials, anthropogenic heat, and air pollutants. Areas with more greenery are often cooler in comparison to areas with more paved surfaces, since asphalt radiates more heat (Saber et al., 2012). Open playgrounds in urban areas can achieve dangerous surface temperatures of over 100°C (212 ℉) (McNeill & Drew, 2022). Anthropogenic heat comes from human activity, power plants, vehicle exhausts, HVAC systems, and more. This heat enters the atmosphere and is more extreme in areas of higher population (Rizwan et al., 2008). The human body performs metabolic activities that generate heat (Fan et al., 2023), and therefore the dense population of humans in urban areas also directly contributes to local temperatures. Urban heat island intensity (UHII) is the measure of the temperature difference between an urban area and the surrounding areas. UHII is the standard for measuring how severe the heat island effects are in specific areas. Some of the more intense examples of UHII measurements include a +12°C intensity in Lodz, Poland, and a +10.5°C intensity in Hong Kong, China (Memon et al., 2009).

The tall and close proximity of urban infrastructure causes radiation trapping, which is when solar radiation that enters an area struggles to escape. This occurs in urban areas due to high amounts of building surfaces that cause solar radiation to be stuck traveling between buildings (Choi et al., 2018). In turn, heat that is produced from solar radiation is both greater and prolonged within urban areas. Figure 6 provides a visual for the pathways in which solar radiation becomes trapped within concentrated urban geometry.

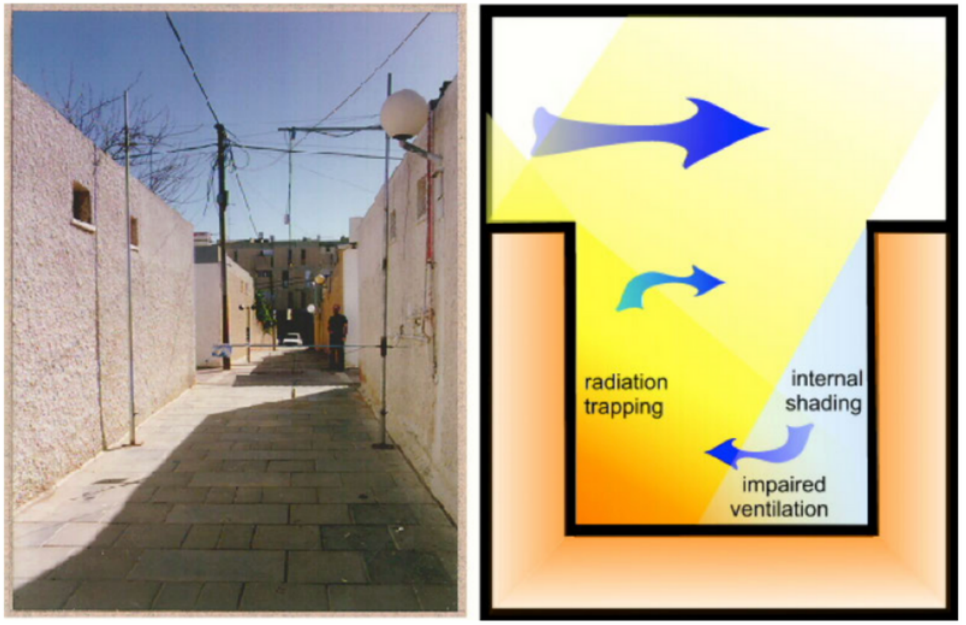

Figure 6: Visualization of radiation trapping (Block et al., 2012).

The material properties of an urban area contribute to its latent heat absorption. Thermal mass is the ability of a material to absorb heat (Reardon et al., 2020). Higher thermal mass is directly related to greater scales of the urban heat island effect (Ryu & Baik, 2023). A prominent material property that affects an object's thermal mass includes its coloration. The colors of an urban environment reflect only basic functions and aesthetic purposes (Li et al., 2018). This results in a disproportionate amount of dark materials compared to that of a natural green environment. Darker colors radiate more heat, and in direct relation, urban areas radiate more heat than natural green areas (Jones, 1968). Materials such as concrete, brick, and tiles are known to have higher heat absorption (Reardon et al., 2020), all of which are commonly used in any typical building and street construction. In heavily developed areas, this means large structures and buildings become large thermal masses that subscribe to urban heat islands (Learn About Heat Islands, 2023).

Vegetation as a Cooling Strategy

Urban heat islands are intensified by the scarcity of vegetation, resulting in temperatures up to 10°C warmer compared to surrounding rural areas (Tan & Siri, 2016). However, research indicates that augmenting greenery within urban landscapes effectively mitigates UHI's (US EPA, 2023).

Various forms of vegetation, such as parks, gardens, trees, grassy areas, green roofs, and green walls, are integrated into urban environments. Plants play a crucial role in reducing temperatures through evapotranspiration—a process involving the conversion of liquid water to vapor through evaporation from soil or transpiration from leaves (LabXchange, 2024). This endothermic process absorbs heat, thereby cooling the surrounding air (Block et al., 2012).

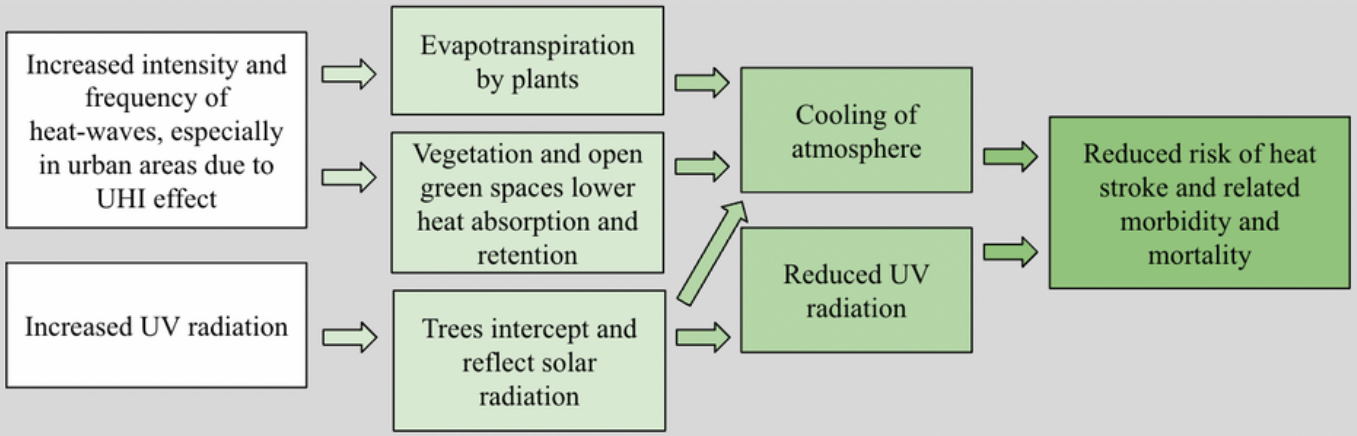

Figure 7: Flow diagram of how vegetation lowers temperatures and reduces UV radiation *Note*. Adapted from T. Knight et al., 2021.

Additionally, trees offer shading benefits by reflection, absorbing, and transmitting solar radiation. Solar radiation includes visible light, heat, and UV rays. Chlorophyll in trees absorbs solar energy, converting it into chemical energy, which is then utilized for various biological processes. This absorption and reflection of solar radiation effectively reduces surface and air temperatures (Block et al., 2012). Figure 7 summarizes the effect of vegetation and trees on temperatures and UV radiation.

While vegetation can be an effective way to reduce temperatures, there are many challenges. The trees must be able to withstand the drought conditions and extreme temperatures of Melbourne (Block et al., 2012). While trees have a shading and cooling effect, they also obstruct and reduce wind flow. Therefore, vegetation design must have a balance between providing trees for canopy coverage while also having enough open area to facilitate nighttime cooling (Knight et al., 2021). Finally, these green solutions can be financially demanding. For instance, Boston, Massachusetts invested over six million US dollars in a green infrastructure conversion project, with smaller projects typically costing over $100,000 USD (MIT, 2023). Despite the complexity of addressing UHIs, vegetation remains the most promising strategy to mitigate the effects of UHIs.

Power of Integrative Storytelling with ArcGIS StoryMaps

Storytelling is the process of sharing narratives or anecdotes. Storytelling is effective in its ability to simplify complex information so that audiences can immerse themselves into better understanding and develop strong empathies (Gupta & Jha, 2022). These qualities make storytelling a powerful tool for raising awareness.

Integrative storytelling involves the use of interactive or engaging forms of media. This includes videos, photos, audio, and graphs. Using video and audio stories that share first-hand experiences leaves the audience with a lasting impression (Rusca, 2018) (Story League, n.d.). Integrative storytelling is a strong tool that illuminates cause and effect relationships and contextualizes data emotionally and realistically. This approach enables individuals to grasp ongoing or predicted data trends with depth and clarity (Kaye & Jacobson, 1999). Integrative storytelling serves as a conduit for understanding interconnectedness of events and phenomena, which helps provide insights into causal chains underlying data trends. By embedding data within narrative frameworks, individuals can discern not just the “what” but also the “why” behind numbers.

ArcGIS StoryMaps is a web-based application developed by Esri. It allows users to create interactive multimedia-rich stories using maps as the central element. With ArcGIS

StoryMaps, users can combine text, images, videos, audio recordings, and other multimedia content with dynamic maps to create compelling narratives that convey information in a visually engaging and interactive manner.

The National Wildlife Federation created an ArcGIS StoryMap titled “The Rise in Extreme Heat.” The goal of their StoryMap was to spread knowledge about the consequences of rising temperatures and push for efforts against climate change (National Wildlife Federation, n.d.). The StoryMap is conceptually organized where it starts by explaining the connection between climate change and extreme heat. The StoryMap then addresses several important heat topics, including health hazards, inequities, and forced displacement.

The story incorporates dynamic and interactive maps, allowing users to explore locational statistics with ease. Users can interactively zoom, pan, and toggle between various map layers to gain insights into spatial relationships and data distribution. Figure 8 shows how the author used an interactive map of the city of Chicago with selectable data layers. Readers are able to select which layers of data are made visible on the map, and can better visualize the

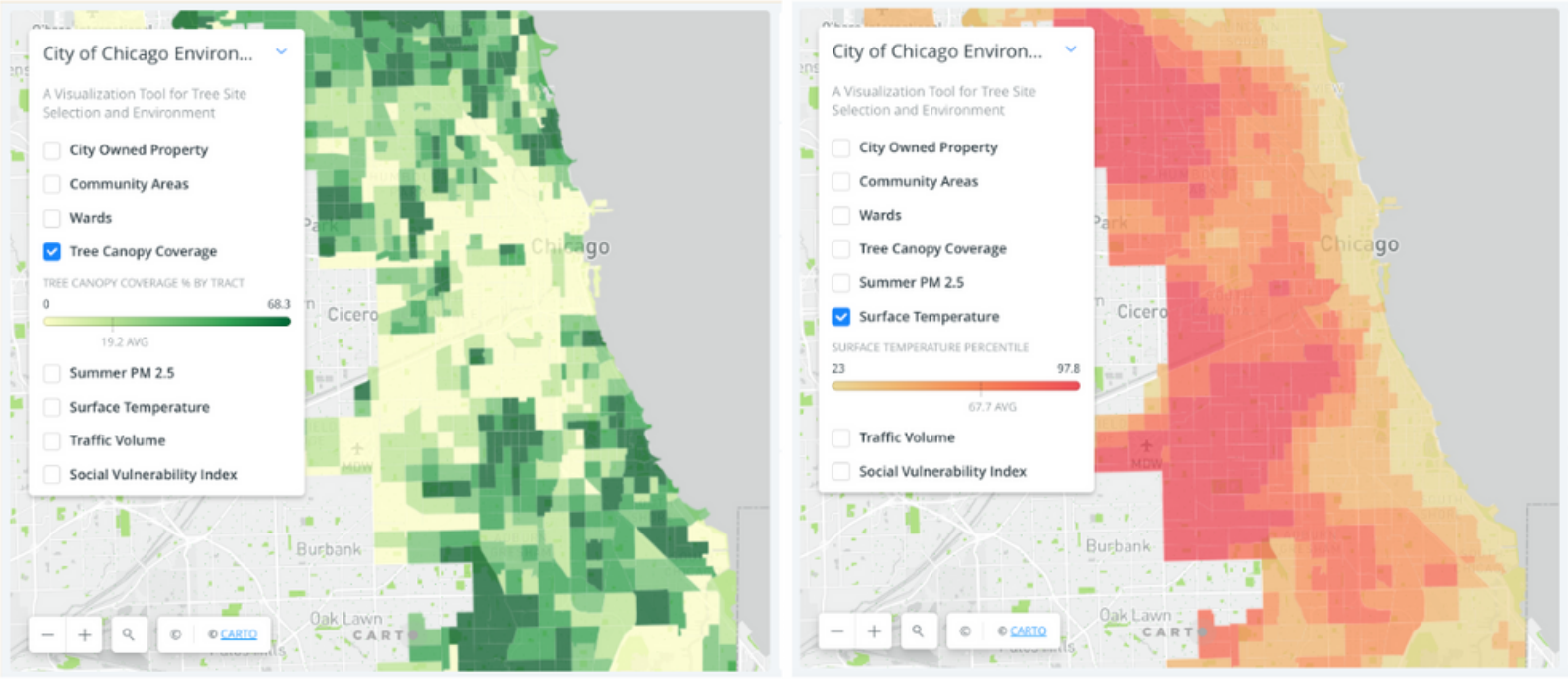

Figure 8: Map of Chicago, Illinois with selectable data layers, including tree coverage and surface temperature (National Wildlife Federation, n.d.)

relationship between different sets of data. In this example, the audience is able to see the direct geographical correlation between the amount of tree coverage and surface temperatures within the city of Chicago.

Other features of ArcGIS StoryMaps include various engaging elements such as clickable hotspots, swipe maps, and embedded links. In Figure 7, the author used an image swiper to show the before and after photos of a schoolyard redevelopment project. This feature requires readers to move the slider in order to see the benefit of green redevelopment, utilizing the reader's curiosity and empowering them to foster deeper understanding of the author's cause.

In an era that is ultimately defined by the deluge of data, the ability to harness the power of integrative storytelling is indispensable. By enabling individuals to comprehend data within broader narrative frameworks, this approach facilitates deeper insights and more informed decision-making. ArcGIS StoryMaps serves as a catalyst for this process, offering a user-friendly platform to weave narratives around geographical data. The synergy between integrative storytelling and ArcGIS StoryMaps holds the potential to drive positive change.

Figure 9: Image swiping feature used in "The Rise of Heat" ArcGIS StoryMap (National Wildlife Federation, n.d.).

Methods

The goal of our project is to tell a story using temperature data and first hand experiences of community members to help Sweltering Cities spread awareness about how extreme heat affects Melbourne's communities. The four suburbs that we focused on throughout our report are Broadmeadows, Dandenong, Wyndham Vale, and St. Albans. As shown in Figure 10, St. Albans is in the west region of Melbourne, Broadmeadows in the north, Wyndham Vale in the southwest, and Dandenong in the southeast. These suburbs were chosen in collaboration with Sweltering Cities. To achieve our goal, we collected temperature data to analyze how extreme heat affects community spaces in each of the four suburbs. We then conducted interviews to understand how extreme heat impacts community members. Finally, we presented our findings in an ArcGIS StoryMap to showcase the dangers of extreme heat.

Figure 10: Locations of St. Albans, Broadmeadows, Wyndham Vale, and Dandenong in the city of Melbourne.

Collected Temperature Data to Analyze How Extreme Heat Affects Community Spaces in Melbourne's Suburbs

First, we assessed how extreme heat affects the communities of Broadmeadows, Dandenong, Wyndham Vale, and St. Albans. We gathered temperature data in various places around each suburb. We determined that areas vulnerable to extreme heat included bus stops, parking lots, parks/green spaces, playgrounds, and benches. These areas have high exposure to sunlight and significant usage by the general public. We compared different bus stops, playgrounds, and benches to determine infrastructure that efficiently protected against heat, and we also compared temperature data from parking lots and green spaces to show how green spaces cool suburbs.

At each area, we recorded the date and time that the measurements were taken and their exact locations coordinates. In addition, we recorded the weather app temperature and conditions at the time of collection. We took note of the demographics and level of activity, as well as context photos and videos, to analyze how temperatures affected the use of the space.

We collected air temperature using a Govee smart thermo-hygrometer air sensor as well as surface temperatures using an Etekcity infrared point-and-read thermometer. The readings helped us analyze how infrastructure, vegetation, and material properties play a role in the impacts of heat.

We used a FLIR C5 thermal camera to capture thermographic images of areas of contrast. Figure 11 shows an example of a thermographic image of a tram stop area. The thermal contrast between the naturally tree-shaded region is shown in cooler tones against the red and hotter, unshaded regions.

Thermography is a fitting media to use for analyzing thermal contrast. It is a noninvasive method of detecting thermal contrast that includes ph through thermal infrared cameras (Asdrubali et al., 2018). Thermography achieves this by capturing the emissivity of facade materials and calculating thermal radiation (Ficapal & Mutis, 2019). Thermal cameras are able to provide estimated temperature readings of surfaces. These surfaces can include playground surfaces, radiated heat from blacktop grounds, and metal benches. The emissivity of facade materials indicates the location of thermal or heat contrast.

Thermal contrast refers to the differences in temperature between two or more objects or regions within a given environment. Analyzing thermal contrast helps assess the impact of infrastructure, vegetation, and material properties under extreme heat.

At each location, we walked around from the train station to find areas that matched our identified spots of interest. We also used Google Maps to help us locate some of these nearby parks and establishments. For example, prior to arriving in Broadmeadows, we located the Broadmeadows Town Park and Broadmeadows Central Mall. On our way to these locations, we found other areas of interest such as playgrounds and other green spaces to collect data from.

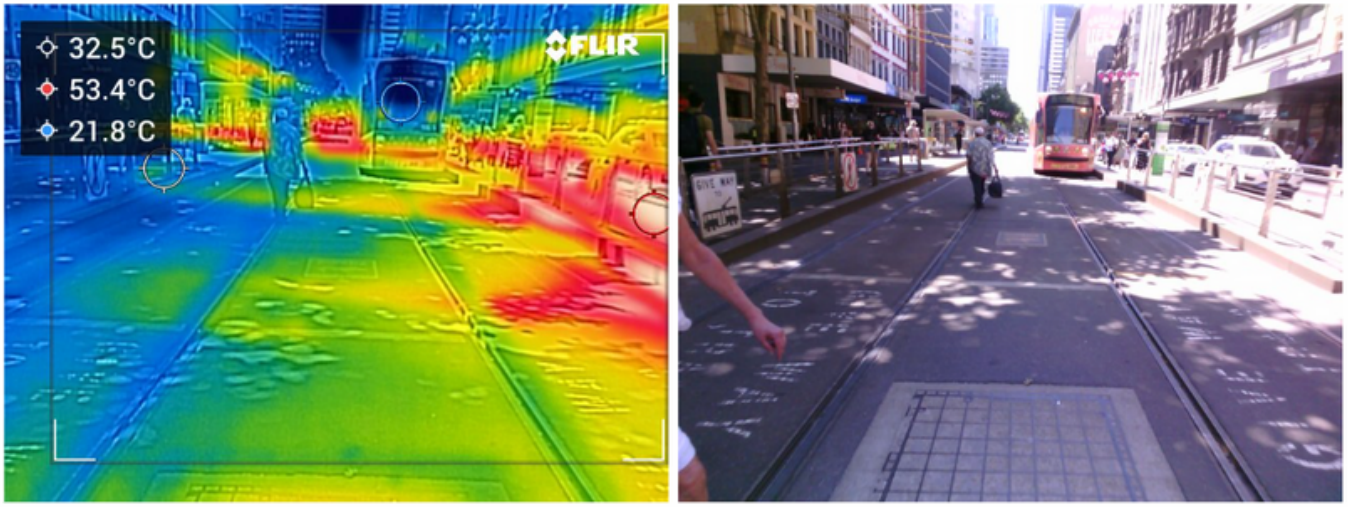

Figure 11: Thermographic photo of partially shaded tram stop at Collins St/Elizabeth St in the Central Business District.

Conducted Interviews to Understand How Extreme Heat Impacts Community Members

Secondly, we investigated how extreme heat affects community members in each neighborhood. We conducted semi-structured interviews with community members of a range of demographics from each suburb. This semi-structured approach allowed for qualitative interviews that can provide rich information which quantitative data cannot show (Bolderston, 2012).

We identified four key groups of people to interview: general community members, community leaders, medical professionals, and outside workers. General community members were interviewed to reflect on their personal experience with heat. Community leaders are those who hold a local government or nonprofit organizational position to help the community and thus represent their organization in their interview. Medical professionals were interviewed to give us insight on the amount of heat-related illnesses that they see and suggest which demographics are most vulnerable. Outdoor workers were asked specifically about their experience and company protections regarding their work in hot conditions. Specific questions that each group was asked can be found in Appendix A, and a verbal consent script for each interview can be found in Appendix B.

Our interviews fall into two different categories: structured and opportunistic. To organize structured interviews, we utilized existing connections and reached out to new places within the community. We prepared for these interviews by writing questions geared towards the interviewee. For example, when we interviewed Dr. Edgar Caballero Aspe from Banksia Gardens, we asked questions about his work there and his experience with a prior WPI project related to climate change. In these structured interviews, we took audio and video recordings using body microphones, an iPhone camera, and a tripod. Opportunistic interviews were conducted spontaneously with people we approached on the street. Since these interviews were with people who were unfamiliar with us, we only took voice recordings as opposed to videos.

With the media gathered from the interviews, we took notes from each voice or video recording. The notes were structured to identify key quotes and concepts and separate the different answers gathered from each question asked.

Created an ArcGIS StoryMap to Showcase the Stories of Extreme Heat

Lastly, we created an ArcGIS StoryMap to showcase the stories of extreme heat. We incorporated visual data we collected in the field, including interviews, weather data, descriptive comments, videos, small scale case studies, and thermographic images. These features allow our data to be well visualized (Scott et al., 2016). We displayed our findings using ArcGIS StoryMap technology and posted a link to the Sweltering Cities website for it to be shared publicly.

We combined the data we collected with photos and videos in a StoryMap to support scientific storytelling in an engaging way, while also being highly informative. Other features StoryMaps utilizes include timelines, customized infographics, quotes, and links. Therefore, while this platform centralizes on communicating geographical data, it also provides a wide range of other media to incorporate. The feature to insert and highlight quotes into the article was also great for our project as we strive to share the voices of community members. We included both video and audio recordings of interviews to personify our data and subsequently strengthened its impact. Many people were not comfortable with being video recorded, whereas a voice recording was less intimidating. Lastly, we included non-interactive images that allowed for contrast and prevented the audience from feeling overwhelmed by all of the other interactive media.

Findings

In this section, we first present general findings about how extreme heat affects individuals and different materials. Then, we dive into the specific data we collected in each suburb.

Extreme Heat Experiences in Greater Melbourne

From our interviews with community members, we found that Melbourne's intense heat reaches dangerous levels and causes discomfort. Particularly, the UV in Melbourne makes the heat more dangerous compared to other tropical areas. Shane, a security guard from Melbourne, says, **"in Melbourne the UV is really really high in the summer, so I have to be really mindful and careful."** He then describes his summer experience in Malaysia where the temperature is often 33°C or higher, but he does not worry about getting sunburned. A grandmother from Ballarat, Megan, explained that her granddaughter is fair skinned, so she has to make sure that her young granddaughter is always covered in sunscreen when they go outside. This exemplifies how parental guardians are responsible for keeping their children safe from the sun. Semra is a 32-year-old that has been living in Kingsborough for about three years. On the hottest days, she likes to stay inside and relax, similar to how she would act on a rainy day. She then says that she enjoys rainy days more than hot days because she feels more energized.

Melbourne's extreme temperatures pose an even greater risk for workers. Zarah, a climate organizer in the United Workers Union, speaks to this danger. She says,

"People can risk their lives, and unfortunately lose their lives, because of violations of health and safety. Unfortunately we have had that [happen], not so much outdoor workers but indoor workers, especially in laundries, and we've had unfortunately members die from heatstroke."

Jenny, a general practitioner from Geelong shares her thoughts on how the workforce is affected by heat:

"They're not going to be able to concentrate with their work and their productivity at work, how their employers see that, support that or not support that, and then how they feel about that in terms of their ability to feel purposeful in their roles, that can then have mental health effects too as well as financial."

Jenny stresses the importance of protecting children and workers from reaching critical health conditions and that, **"it's really vital to have these preventative care strategies in place because otherwise the hospitals will just get burdened as the planet heats up."** It is made clear by Zarah and Jenny that there are current working conditions that threaten mental and physical health, stressing the importance of allowing workers the ability to take care of themselves.

Fiona is a women's health and engagement officer with a strong background in social work. She works to promote health in community engagement with refugee women and prevent violence against southeastern refugee women. We

asked Fiona to share her thoughts on how heat has affected migrant groups whom she works closely with. Fiona states that,

“Adult children finding employment in construction or outdoor industry—really manual type labor—a lot of them would come home—like—completely wrecked. Y’know—exhibiting heat exhaustion, verging on having—getting close to kind of a heat stroke—kind of illness. And just feeling overwhelmed about what to do and trying to do all the things that they know how to do about keeping them cool—trying to give them water. But it would never actually eventuate into calling for emergency services"

And while it is apparent that migrant workers coming home in life threatening decisions would look to emergency services. But Fiona explains that a commonality for these migrant communities is that,

“Being unfamiliar and anxious about calling emergency services when they know that the operator is going to speak english. A lot of them were not aware that there would be an interpreter put on the phone as soon as they’ve identified what language—and that was a barrier for them—a lot of anxiety around that so then they try to manage by themselves which is obviously—like—if it is a heat stroke—that’s an emergency—that’s like—you will die.”

While there are emergency services in line for all of the public to use, social and language barriers prevent migrant communities from being able to fully benefit from them. As a result, specific groups of migrant workers with manual labor jobs who are exposed to extreme heat conditions actively get by without the help of emergency services. This stresses the importance of not only safe working conditions and fair treatment of employees but also how important it is to make emergency services more accessible for everyone that may be in a heat-related crisis.

In addition to interviews, surface and air temperature data was taken in public areas. We found that wood and rubber are most susceptible to becoming dangerously hot in the sun, whereas lightly colored pavement does not propagate as much heat. Surface temperatures of wood and rubber playground materials consistently exceeded 60°C on a day that was only 29°C. Surface temperatures greater than 60°C are considered unsafe and can cause first-degree burns within short lengths of contact (Safety Action, 2019). These temperatures indicate that the heat intensity of playground structures poses risk of burns to children. When comparing the temperatures of similar materials that were different colors, we found that dark surfaces reached higher temperatures than lighter colored surfaces. Additionally, the measured air temperatures were consistently higher than the recorded weather data. This shows that typical weather data apps can partially mislead people to think that heat conditions are not as bad as they actually are. This discrepancy is consistent with the effects of urban heat islands. It is plausible that the measured air temperature was consistently higher than the weather data due to the thermal properties of surrounding infrastructure. Canopy

coverage was found to consistently reduce surface temperatures by over 10°C. Although both green and artificial canopies provide cooling areas, greenery absorbs heat whereas non-living materials propagate more heat above the canopy. For example, the difference between surface temperatures of fake grass and real grass were up to 25°C. All of these general findings were found throughout every suburb and were used to give us insight into which stories we should present in the StoryMap.

Extreme Heat Experiences in Broadmeadows, Dandenong, St. Albans, and Wyndham Vale

To analyze extreme heat in each suburb, we used census data in addition to interviews and temperature data. Looking at all four suburbs in comparison, we saw that St. Albans, Broadmeadows, and Dandenong have a significantly lower median weekly household income than that of Greater Melbourne and Victoria, and a relatively low canopy cover as well, which can be seen in Table 1 (Australian Bureau of Statistics, 2021). Wyndham Vale is a newer city that only has 2.4% canopy coverage, the lowest in Greater Melbourne (Wyndham City Council, n.d.).

Broadmeadows

Broadmeadows is a suburb located about 15 km north of the Melbourne city center, within the city of Hume. It is located on the traditional lands of the Wurundjeri Woi-wurrung aboriginal tribe (Hume City Council, 2024). In 2021, the population of Broadmeadows was 12,524, which is roughly 2,000 inhabitants more than the population was in 2011. The

Table 1: Demographics of St. Albans, Broadmeadows, Wyndham Vale, Dandenong, Melbourne, and Victoria from the 2021 census (Australian Bureau of Statistics, 2021).

Region	Canopy Coverage	Median Weekly Household Income	Aged 0-9 years	Aged 65+ years
St Albans	5.3%	$1,205	11.2%	17.8%
Broadmeadows	6.6%	$1,151	14.5%	10.6%
Dandenong	6.0%	$1,267	13.4%	12.7%
Wyndham Vale	2.4%	$1,766	18.4%	7.3%
Melbourne	16.2%	$1,901	12.2%	15.1%
Victoria	-	$1,759	12.0%	16.8%

median weekly household income is $1,151. With the increase of residents comes an increase in renters, as the percentage of renters increased from 38.3% to 48.9% from 2011 to 2021 (Australian Bureau of Statistics, 2021). Broadmeadows is culturally unique, as 36.1% of residents are Muslim, compared to 4.2% of residents across Victoria. Additionally, only 41.1% of residents were born in Australia, compared to 65.0% in all of Victoria (Australian Bureau of Statistics, 2021). Vegetation cover in the municipality of Hume, including Broadmeadows, was 5.3% in 2018, which was the third lowest percentage across Melbourne (Hurley et al., 2019). A study done by the Victorian Center for Climate Change Adaptation Research in 2012 found that in Broadmeadows from 2000 to 2009, “tree presence declined by only 4% on private land and increased by 38% on public land, due to active tree planting by Hume City Council” (Block et al., 2012). Broadmeadows is accessible from the Melbourne City Circle via the Craigieburn train line. Broadmeadows is home to multiple schools and Broadmeadows Central shopping center.

We collected temperature data from the Broadmeadows Train Station platform, the Broadmeadows Central Shopping Center, the Broadmeadows Town Park, the Valley Primary School, and Banksia Gardens. Temperature data is summarized in Table 2. Figure 12 shows an analysis of a train stop bench on a hot day.

Table 2: Summary of temperature data collected in Broadmeadows

Broadmeadows				
Location	**Weather App Air Temp (°C)**	**Measured Air Temp (°C)**	**Surface Type (assume unshaded unless specified as shaded)**	**Surface Temp (°C)**
Broadmeadows train station	28	35	Black metal bench	47.7
Broadmeadows Central sidewalk in parking lot	29	39	pavement	53.8
			shaded concrete	28.1
			sunny concrete	45.7
Broadmeadows Town Park	30	37	grass	34.1
			concrete	48
			wood chips	56.4
			rock	49.7
			wood bench (material unsure)	48.9
			metal bench arm	47.9
Broadmeadows Valley Primary School Playground	30	43	fake grass	65.7
			metal slide	43.4
			wood chips	62.6
			plastic slide	50.1
			pavement	62
			wood bench	60.9
			other fake grass	63.1
			metal playground floor	54
			fake grass in shade	35
Banksia Gardens			sunny grass	37.9
			shaded grass	28
			sunny woodchips	54.6
			shaded woodchips	32.1

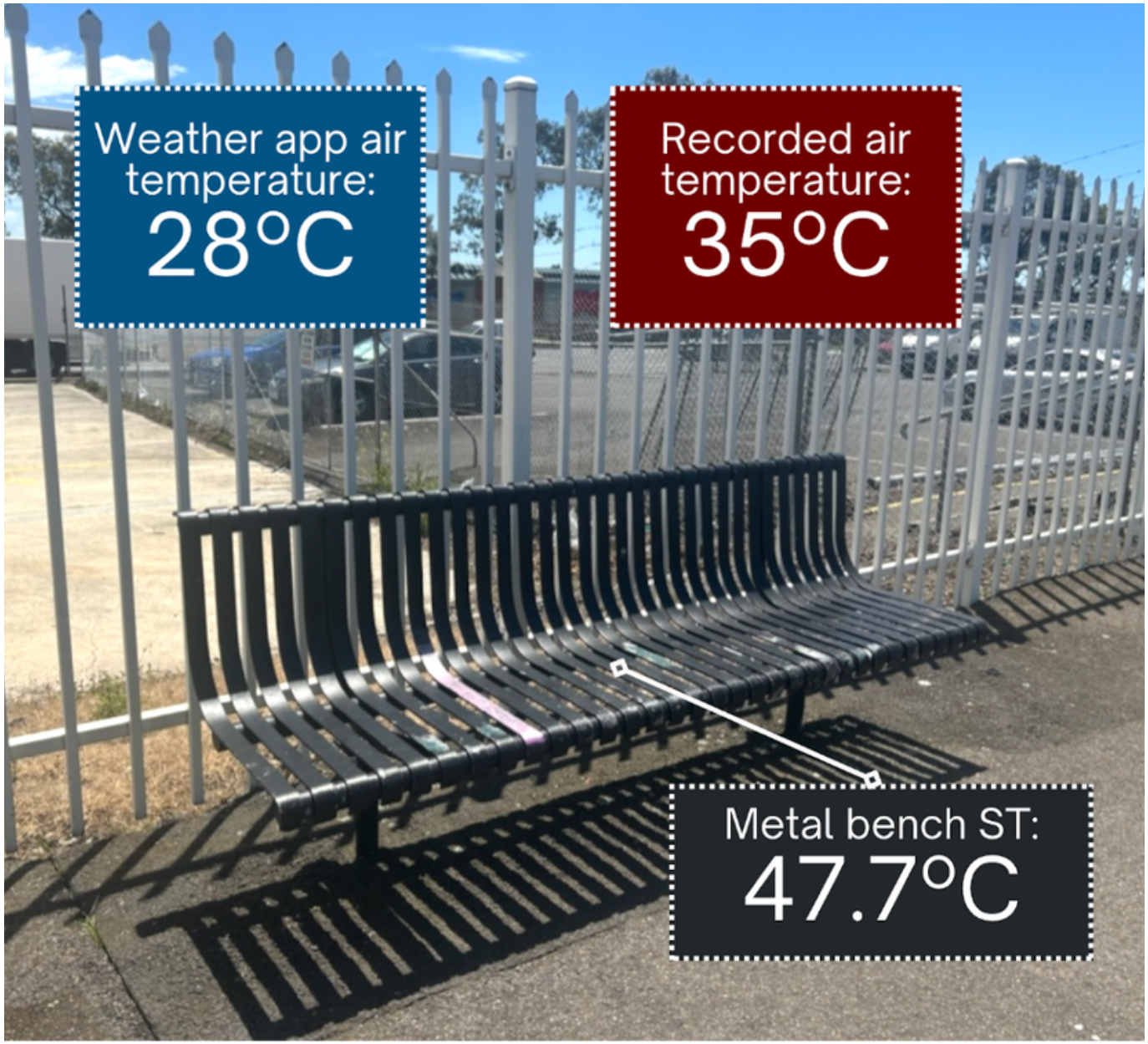

Figure 12: Image of Broadmeadows Train Station with the weather app temperature, recorded air temperature, and surface temperature of the bench.

In Broadmeadows, we interviewed five general community members, one outdoor worker, and a member of Banksia Gardens Community Services. The five general community members–Louis, Natalie, Adam, Amelia, and Lani–were all youth workers for Hume City Council. Louis described Australia's heat saying, **"the sun…it's quite—it's different from other places in the world like when it touches your skin you can feel that it's bad - it like bites you."** Amelia remarks about the heat saying, **"I can't stay in the heat for too long… and I think because the sun is so like… searing hot. . . even if it rains a little here in Melbourne then it gets really muggy… so it's just like horrible to stay in."** They also shared that public transport can get too hot to travel in, whereas traveling in a car is the most comfortable option. When asked about their pets, they described giving them icy treats, water sprays, and boots to protect their paws from the hot surfaces.

Adrian is a pipe layer who knows the importance of staying safe and hydrated in the heat. He says, **"When it gets to a certain level, if the boys are struggling, I just tell 'em, 'go in the shade, rehydrate, drink water, keep your fluids up. It's common practice with what we do because we've been doing it for so long."** He believes that this practice, in addition to stopping work at 36°C and wearing long clothing to protect their skin, is reasonable and sufficient protection from Melbourne's heat.

At Banksia Gardens Community Services, we interviewed Dr. Edgar Caballero Aspe, who is the education and sustainability coordinator there. We were able to talk to him about efforts being made by the organization to reduce temperatures in the area, and Edgar was able to tell us about how they are attempting to implement "food forests." Food forests are made by planting both trees and other ground plants that produce fruit, herbs or products that can be used for medicinal purposes. Banksia Gardens has also been putting a lot of efforts towards planting trees, and Edgar explained that, **"The priority is just to have big trees that will create more and more shade, and there is lots of research that says if you beautify a space like that levels of violence can reduce, mental health would increase which is a big issue with our community, so it touches on all elements."** Edgar also talked to us about the importance of increasing biodiversity and how, **"If we can increase biodiversity all around this space we'll reduce heat. Obviously we are targeting big canopy [areas], plants that can cover, create shade, absorb heat and be productive."**

Terina, who is also a part of the Banksia Gardens enterprise, is the operations manager for the Common Bean Cafe, shown in Figure 13. When working at the cafe, Terina states that,

"We're so subject to the elements here… actually inside the container is usually about 4-5°C hotter than it is outside. Mainly because there's not a lot of airflow and because we've got stoves and ovens in there. So we closed up when it got to I think it was 35°C out here but in there it was sort of 38°C. We've got a policy that we can't work beyond 37.5°C."

This expands on the issues that workers are faced with when dealing with hot days. Despite having an occupation that is not generally classified as outdoor work, Terina also struggles with radiating heat inside of the cafe and is consistently exposed to the outdoor conditions. On top of this, Terina is also a mother who states that, **“now it’s just unbearable for the kids. My kid is just covered in sunscreen all day everyday and he hates it.”**

In Broadmeadows we also interviewed a senior citizen who stated that she is unable to sleep upstairs because it is too hot. She has been living in public housing for over 30 years, and air conditioning is only available downstairs. This is a strong indicator that housing arrangements are insufficient against climate conditions and vulnerable communities that rely on public housing are affected.

Figure 13: Photo of the Common Bean Cafe in Broadmeadows.

Dandenong

Dandenong is a suburb about 35 kilometers southeast of the Melbourne city center, located in the city of Greater Dandenong. It is located on the traditional lands of the Bunurong indigenous people (Greater Dandenong City Council, 2024). The population in Dandenong has risen by over 5,000 residents from 2011 to 2021. In 2021, the population was recorded to be 30,127. The median weekly household income is $1,267. Similar to Broadmeadows, Dandenong has a high percentage of Muslim residents (34.1% in 2021) as well as a low percentage of residents born in Australia (30.9%). Afghanistan, India, and Sri Lanka are the next three largest countries of birth for residents of Dandenong. The three largest occupations of Dandenong residents are technicians and trades workers, laborers, and machine operators and drivers, making up 50.7% of the population. The percentage of renters is also higher than the Victorian average, sitting at 52.7% in 2021 (Australian Bureau of Statistics, 2021). The municipality of Greater Dandenong had 6.6% vegetation cover in 2018, one of the lower percentages across greater Melbourne. Dandenong is accessible from the Melbourne city circle via the Cranbourne train line.

We collected temperature data from Dandenong Station, Dandenong Station Car Park, Dandenong Park, Red Gum Rest, and a recreational park at Dandenong Park. Temperature data is summarized in Table 3. Figure 14 shows the shockingly high surface temperature of the rubber ground.

Figure 14: Image of the empty Dandenong Recreational Park with the weather app temperature, recorded air temperature, and surface temperature of the blue rubber.

Table 3: Summary of temperature data collected in Dandenong.

Dandenong				
Location	**Weather App Air Temp (°C)**	**Measured Air Temp (°C)**	**Surface Type (assume unshaded unless specified as shaded)**	**Surface Temp (°C)**
Dandenong Station	29	36.8	black pavement	53.3
			white pavement	36.7
			shaded black pavement	25.4
Dandenong Station Car Park	28	33.1	pavement	50.3
			unshaded gravel	45.7
			shaded gravel	32.3
			unshaded plant	34.8
			shaded plant	31.1
Dandenong Park	29	35	unshaded wooden bench	56.5
			shaded wood bench	29.1
			unshaded grey pavement	41.5
		31 under tree canopy	unshaded gravel/dirt	46.4
			shaded pavement	31.8
Red Gum Rest - Dandenong playground	29	42.8	unshaded wooden walkway	68.1
			shaded wooden walkway	28.7
			unshaded metal slide	40.2
			playground ground surface (rubbery cement-like) unshaded	60.2
			uncovered wooden bridge	65.7
			unshaded woodchips	59.3
			unshaded sidewalk	53.1
			unshaded rubber ground	62.6
			Unshaded wooden play structure platform	70.5
		30.5 under tree canopy	Shaded wooden play structure platform	35.5
Recreational Park - Dandenong Park			unshaded wood chips	53.7
			metal pull up bar	44.5
			grass	37.6
			sit up bench (plastic)	62.1
			blue rubber ground	68.6
			dirt/gravel	45.3

In Dandenong, we interviewed a few members of the Dandenong City Council and a general community member that was resting at Dandenong Park, Adimora Onono. Adimora is a 30 year old student and legal practitioner from Nigeria who has lived in Australia for two years. He explains that the heat in Australia is very different from the heat in Nigeria, saying, **“In Melbourne, it’s something very extreme, and it’s making me uncomfortable.”** He says that he must push through the discomfort that heat causes him when commuting to his job and classes.

At Dandenong City Council, we met with Jessica Harrison who is the team leader of sustainability planning for the city of Greater Dandenong, Scott Walker who is the Emergency Management Coordinator for the city of Greater Dandenong, and Susie who is the Emergency Management Project Officer for the city of Greater Dandenong. They emphasized the issue of having a large population of people in the city that do not speak English and therefore need to be accommodated for information sent out by the council such as pamphlets or their instructional videos on their website. Another important point emphasized by Scott was the fact that, **“We have a lot of schools [where] the infrastructure is quite old, so a lot of the schools are not air conditioned and they might be quite older buildings.”**

St. Albans

St. Albans is a suburb of Melbourne located about 17 km northwest of the city center in the city of Brimbank. It is located on the traditional lands of the Wurundjeri Woi-wurrung aboriginal tribe (Szwed, 2022). The population of St. Albans in 2021 was 38,042, which was roughly a 3,000 person increase from 2011. The median weekly household income is $1,205. Only 32.5% of St. Albans residents were born in Australia, compared to 65.0% across all of Victoria (Australian Bureau of Statistics, 2021). The next highest birth place was Vietnam, with 21.5% of residents being born there, followed by India and the Philippines. The top three religions were catholic, no religion, and buddhism, making up 60.8% of the suburb's population . The three largest occupations of St. Albans residents are laborers, technicians and trades workers, and machine operators and drivers, making up 47.1% of the population (Australian Bureau of Statistics, 2021). Vegetation cover in the municipality of Brimbank is only 6.0%, one of the lowest across Greater Melbourne (Hurley et al., 2019). St Albans is accessible from the Melbourne City Circle via the Sunbury train line. St Albans is home to multiple schools, including Victoria University, and Sunshine Hospital.

We interviewed an RMIT university student, Kim, from St. Albans. She shared her thoughts on how heat has affected the elderly and the general willingness to be outdoors. Kim states that, **"A lot of the older people living in rental homes do have trouble trying to stay at home because a lot of the homes don't have cooling or air con,"** and that, **"having to experience consecutive days above the limit of what people are able to endure… it becomes so much more difficult to do daily routines, having to go to work, and even sometimes staying at home becomes too much."** It is evident that Kim believes the heat has a strong and negative impact on both herself and the elderly. We then asked Kim to express her concerns about St. Albans' public infrastructure, more specifically how well it addresses heat conditions. Kim says, **"the way that the trees [in the park] are situated is they line the park so they do not provide much shade… On the days I go there not many people use the park, they are relatively empty"** and that, **"there is some shading at bus stops… but when it comes to adequate shading it could be better."** While there are trees and bus shades, residents are not adequately protected when commuting or using public spaces.

We collected temperature data from Silvan Court Playground, Kevin Flint Memorial Playground, and Cairnlea Drive Route 423 Bus Stop. Temperature data is summarized in Table 4. Figure 15 shows one of the playgrounds that was analyzed in St. Albans.

While walking to the Kevin Flint Memorial playground on a day that was 38°C, we saw roof workers outside at around 2:40pm. While only spectating for under a minute, we saw one worker hydrating from up on the rooftop. This shows that although certain companies have rules to stop work at 32°C or 34°C, not all workers are protected equally. These roof workers were either not protected by the union, or breaking the health and safety regulations like Zarah had mentioned.

Table 4: Summary of temperature data collected in St. Albans.

St. Albans					St. Albans				
Location	**Weather App Air Temp (°C)**	**Measured Air Temp (°C)**	**Surface Type (assume unshaded unless specified as shaded)**	**Surface Temp (°C)**	**Location**	**Weather App Air Temp (°C)**	**Measured Air Temp (°C)**	**Surface Type (assume unshaded unless specified as shaded)**	**Surface Temp (°C)**
Kevin Flint Memorial Playground	37	37.3	blue rubber	68.4	**Silvan Court Playground**	37	44.7	black metal platform	62.3
			black plastic seat	68.1				shaded black metal platform	40.6
			woodchips	60.3				woodchips	61.8
			green plastic slide	54.6				shaded woodchips	39.1
			black plastic swing	61.8				grey wooden bench	58.2
			silver plastic handle (material unsure)	44.1				shaded grey wooden bench	39.2
			blue plastic slide	52				black rubber ground	78.5
			black concrete / pavement	54.1				black plastic swing	59.2
			light grey plastic platform	60				seesaw seat (white metal)	47.1
			pink plastic slide shaded	39.5				seesaw handles (blue metal)	51.4
Cairnlea Drive Route 423 Bus Stop	38	35.1	shaded grass	33.7				green plastic slide	58.3
			grass	43.8				shaded green plastic slide	41.2
			silver metal bench (shaded by transparent glass)	43.6				wooden bridge	58.5
			silver metal bench shaded	41.3				pavement / concrete / cement	59.8

Figure 15: Image of the empty Silvan Park Playground with the weather app temperature, recorded air temperature, and surface temperature of the wood chips.

Wyndham Vale

Wyndham Vale is a suburb of Melbourne, located 31 kilometers southwest of the city center in the city of Wyndham. It is located on the traditional lands of the Bunurong and Wadawurrung indigenous peoples (Wyndham City Council, 2024b). Demographically, Wyndham Vale is unlike the other three suburbs described above. Wyndham Vale's population has increased from 17,304 residents in 2011 to 20,518 residents in 2021. The median weekly household income is $1,766. According to the 2021 Australian census, 54.7% of Wyndham Vale's residents were born in Australia, which is much closer to the average across Victoria, 65.0%. The top two religious affiliations were catholic and no religion, making up 46.2% of all residents (Australian Bureau of Statistics, 2021). The top two occupations held by residents here are professionals and clerical and administrative workers. Wyndham Vale renters make up 31.4% of the population, which is relatively low. Based on this data, Wyndham Vale has a high median weekly household income and low percentages of immigrants and renters compared to the other three suburbs. However, Wyndham Vale has low vegetation coverage in common with them. With only 2.4% vegetation cover in 2018, the municipality of Wyndham had the lowest vegetation cover percent in the entirety of Greater Melbourne. A study done by the municipality in 2017 shows that the canopy cover increased by 2.4% from 2007 to 2017, however they still have room for improvement (Kaspar, 2019). The Wyndham Vale municipality is working to continue to increase canopy cover through a long term plan, structured from now until 2040 (Wyndham City Council, 2024). Wyndham Vale was historically open farming land, but began developing as a residential area in the 1980's (Monash University & University of Queensland, 2015). Wyndham Vale is accessible from the Melbourne city circle via the Werribee train line.

We collected temperature data from the Wyndham Vale Manor Lakes Linear Park and Playground. Temperature data is summarized in Table 5. Figure 16 shows a thermal analysis of a front yard with fake grass, which is representative of a typical front yard in Wyndham Vale, and Figure 17 shows thermal contrast of real and fake grass.

Table 5: Summary of temperature data collected in Wyndham Vale.

Wyndham Vale				
Location	**Weather App Air Temp (°C)**	**Measured Air Temp (°C)**	**Surface Type (assume unshaded unless specified as shaded)**	**Surface Temp (°C)**
Manor Lakes Linear Park Bench	30	44	wood bench	64
Playground at Manor Lakes Linear Park	31	40	wood chips	62.8
			black metal playground eqpt	55
			green metal playground eqpt	64.9
			black rubber	79
			beige metal playground eqpt	51.7
			green plastic slide	71.3
			blue rubber	81.8
			grey metal playground eqpt	62.2

Figure 16: A front yard of entirely fake grass in Wyndham Vale with grass surface temperature, weather app temperature, recorded air temperature.

We interviewed June and Colin Styles, a married couple, who are residents in Wyndham Vale. Both June and Colin are volunteer members in projects that help to clean up their local communities. In the interview, we asked June and Colin to speak on the housing developments that are taking place in their community. June stated,

“They’re doing it badly, they’re putting in so many houses, so close together. The streets are very very narrow. So, you can’t always plant a tree that's going to have canopy or give shade in the future. And also because the yards are very small, people are putting in false grass which is virtually plastic, which again heats up and gets really really hot. So then you don’t even get the water to go through it properly and into the soil.”

Colin then added,

“There’s no cooling mechanism. The newer developments —they’re just cramming them in…the more you can jam

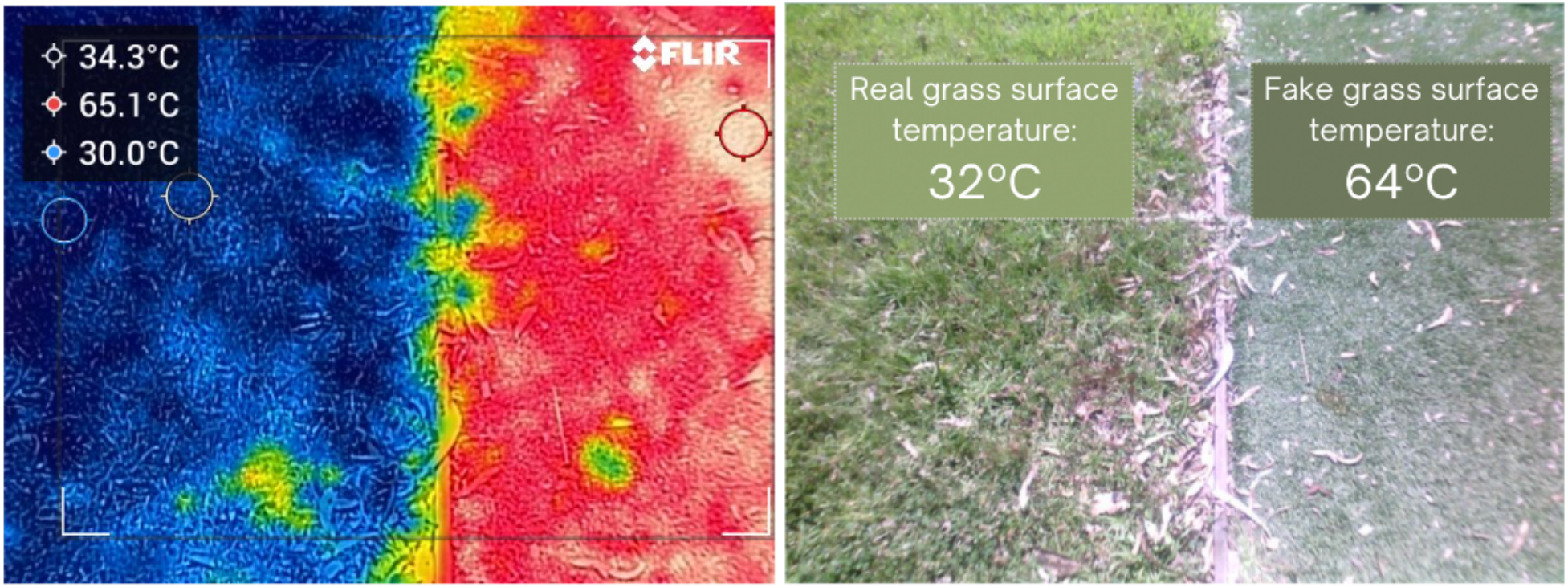

Figure 17: Thermal (left) and normal (right) image of fake and real grass.

into an area the more money you'll make, it's a hot suburb and there's nothing to stop it… People are going to the convenience of the artificial grass and stones and whatever else they have to make it look pretty. But they all absorb and radiate the heat… People build with dark roofs [and] the heat pumps are put outside the houses which just generates even more heat, it's very worrying."

It's clear that some residents within the Wyndham Vale community are generally dissatisfied with both the heat and construction of their suburb. They share the same concerns about artificial materials and how the dark complexion of buildings are contributing to the overall heat.

While in Wyndham Vale, we were able to talk to a sign writer that was doing work near the station and a mother at the Manor Lakes Playground. The sign writer says that they drink lots of water, take breaks, wear hats, apply sunscreen, stay out of the sun, and try to go into air conditioning to stay cool. He says, **"[We] can't get away with having shorts or any of that stuff, got to have full PPE going on. It's annoying because you want to cool down and you just can't and you're out on a train station, good luck. So it is what it is."** He does, however, believe that his working conditions properly accommodate higher temperatures. Even though he's not part of the union, they stop work once it gets to 34°C. He also says, "the Melbourne heat, I feel like the sun hit you different here." This statement is similar to how the youth workers described Melbourne's heat. The mother at the playground was watching her child at the playground and explained that she usually only takes her daughter outside in the evening and goes to the pool to keep cool.

Deliverable

To showcase the effects of extreme heat, we organized our temperature and interview data to tell a story about each of the suburbs we studied. Each suburb had an overarching theme. We did this to tell the stories in an engaging way and avoid repetition of findings and temperature data. In addition to the stories of each suburb, we included (i) a brief introduction, (ii) background on climate change, rising temperatures in Melbourne, and urban heat islands, (iii) a methodology section, (iv) an introduction to the four suburbs, and (v) a conclusion.

We start off our StoryMap with the eye-catching title, “Beyond Thermometers,” and a background video of long grass taken in Wyndham Vale to get our readers into the feeling of being outside on a hot day, as you can see in Figure 18.

Figure 18: A screenshot of what readers first see upon opening our StoryMap.

Before diving into background information, we wrote a paragraph explaining the purpose and intentions for the StoryMap. We then display striking quotes about Melbourne’s unique heat and high UV to engage readers, as shown in Figure 19.

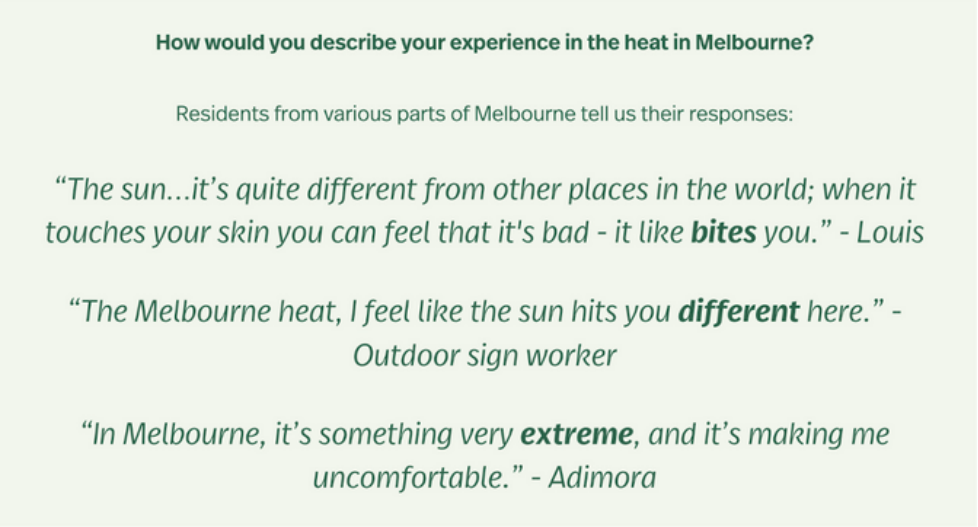

Figure 19: A screenshot of the quotes displayed on the StoryMap.

For background, we have a brief overview of extreme heat in Melbourne resulting from climate change with heat projections for Melbourne over the next several decades. We included a section detailing urban heat islands and their effect on cities to give background to our findings. To supplement the information about urban heat islands, we included an interactive urban heat map of Melbourne, as seen in Figure 20, where readers can zoom in or out, and also select different areas to find their names and other more specific information to the area.

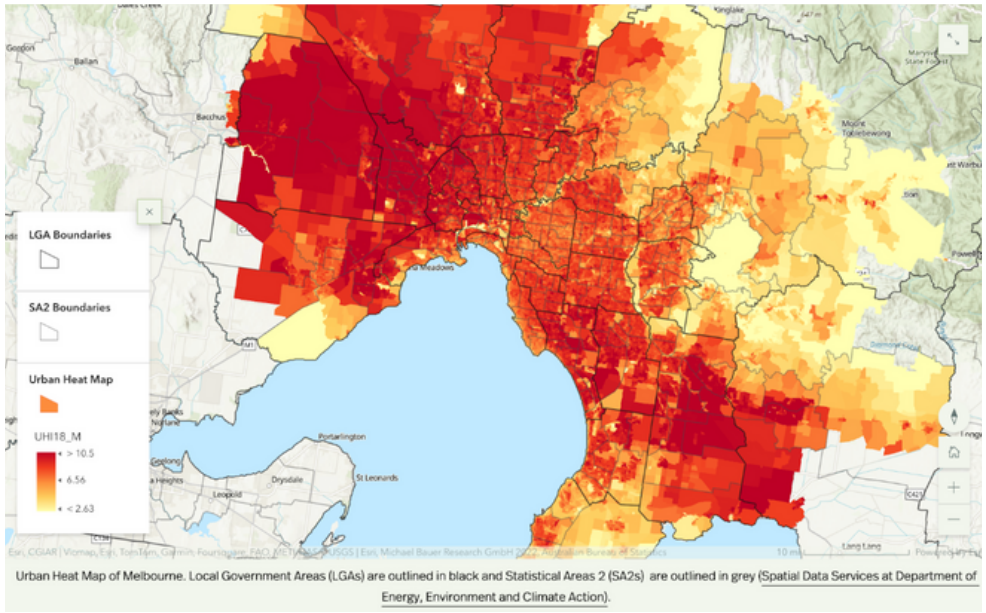

Figure 20: A screenshot of the interactive Urban Heat Map of Melbourne from our StoryMap.

Along with the urban heat map, we include two other interactive maps: heat vulnerability index and vegetation coverage.

In our methodology section, we explain how we determined what objects and places to take temperature data from, what data was recorded for each individual location, and what temperature recording instruments were used. We also included a collage display of labeled photos of team members collecting data out in the field as seen in Figure 21.

Next, we introduced our suburbs with the sidecar feature on StoryMaps. This allows for audiences to scroll down and read background information while the location of the suburb being described is shown on a map. A snapshot of this feature is shown in Figure 22.

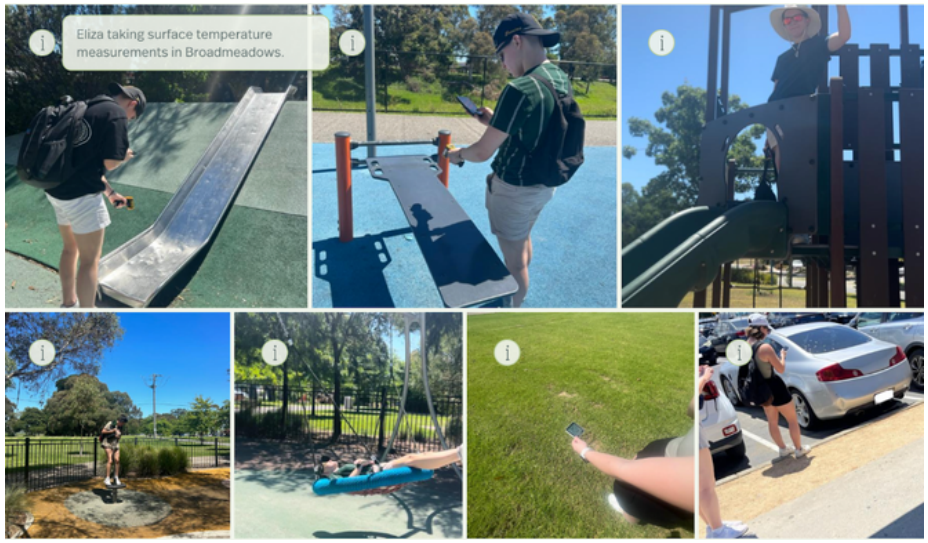

Figure 21: A screenshot from our StoryMap of a collage of images of our team collecting data. Each image has a brief description, as shown on the image in the top left.

Figure 22: A screenshot of the scroll through map introducing each suburb from our StoryMap.

We then created a table that displays tree canopy coverage, median weekly household income, population, and percentage of people born outside Australia for each suburb and for Greater Melbourne, which can be seen in Figure 23.

Region	Tree Canopy Cover	Median Weekly Household Income (AUD)	Population	Born Outside of Australia
Wyndham Vale	2.4%	$1,766	17,304	45.3%
St. Albans	6.0%	$1,205	38,042	67.5%
Broadmeadows	5.3%	$1,151	12,524	58.9%
Dandenong	6.6%	$1,267	30,127	69.1%
Greater Melbourne	16.2%	$1,901	4,917,750	40.1%

mographics of St. Albans, Broadmeadows, Wyndham Vale, Dandenong, and Greater Melbourne (Department of Transport and Planning) (2021 Australian Censu

Figure 23: A screenshot of the 2021 census and Department of Transport and Planning data from our StoryMap.

One of the biggest things we noticed when walking into Wyndham Vale was the densely packed housing and dark roofs, as well as the lack of trees. This drove us to talk about how lack of canopy cover, dark roofs, and fake grass contribute to the UHI effect in Wyndham Vale. To support this, we used temperature data comparing fake and real grass, aerial maps of the new housing developments, and a voice recording from June. Figure 24 shows a section of our StoryMap where we include a slider image of a normal and thermal picture to highlight the effectiveness of vegetation in cooling surrounding areas.

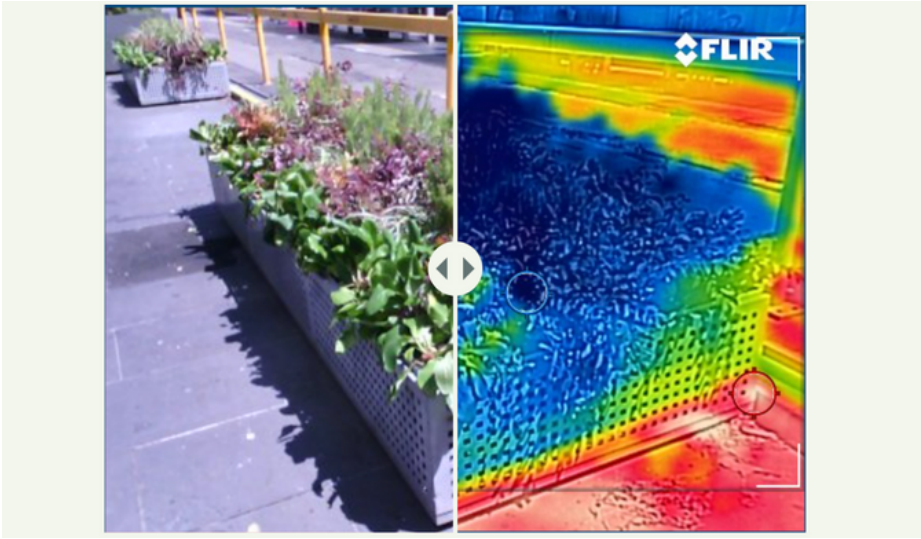

Figure 24: A screenshot of the slider image depicting the comparison of a normal and thermal image of vegetation from our StoryMap.

The next narrative of our StoryMap took place in St. Albans, where we explored how extreme heat poses a serious risk to vulnerable populations, focusing mostly on children. We displayed background about how children need help staying safe in the heat and that leaving children in cars is never an option. Then, we created a case study of a playground to take readers into the dangers of playgrounds on hot days. We utilized the sidecar feature again, but this time with changing images instead of changing locations on a map. Figure 25 depicts a part of the playground sidecar feature from our StoryMap.

Figure 25: A screenshot from our StoryMap showing one of the aspects from the playground case study showing the surface temperatures recorded for different parts of the seesaw.

To supplement the case study, we used temperature data, research on dangerous surface temperatures, interviews from mothers, interviews from medical professionals, and a map of St. Alban's 18 unshaded playgrounds. We then delve into other demographics that are vulnerable to heat, including women experiencing menopause, migrant communities, and people with pre-existing health conditions. We used interview data from Dr. Jenny Huang, Fiona, and Kim to support this section.

In Broadmeadows, we were inspired by the stories from the social enterprise of and public housing estates near Banksia Gardens to share experiences of transportation, working, and living conditions in extreme heat. We emphasized the dangers of waiting at bus stops and train stations for an unexpected period of time and showed data from train stations, bus stops, and hot car parks. Then, we showcased Terina's story at the Common Bean Cafe to communicate the struggles of workers that are exposed to extreme heat. Figure 26 shows how we used the video feature in StoryMaps to incorporate a clip from Terina's interview.

Figure 26: A screenshot of the scroll through map introducing each suburb from our StoryMap.

We also included interview data from Adrian and Zarah. The last section in Broadmeadows shares perspectives of living in the public housing estates next to Banksia Gardens with interviews from Helen and other residents there. We wrap up the section with a video of Banksia Gardens overlaid with our interview from Dr. Edgar Caballero Aspe about how adding greenery and beautifying the space can have profound benefits.

Dandenong's section is focused around how local communities are taking initiative to make Melbourne safer, but state and federal policies need to reflect these changes as well. We presented our data from Dandenong on canopy coverage and shaded materials to introduce one of the efforts being made by Dandenong City Council. We then present the Dandenong City Council's efforts through interview quotes from Jessica and Scot, which can be seen in Figure 27. Further background on existing policies can be found in Appendix C.

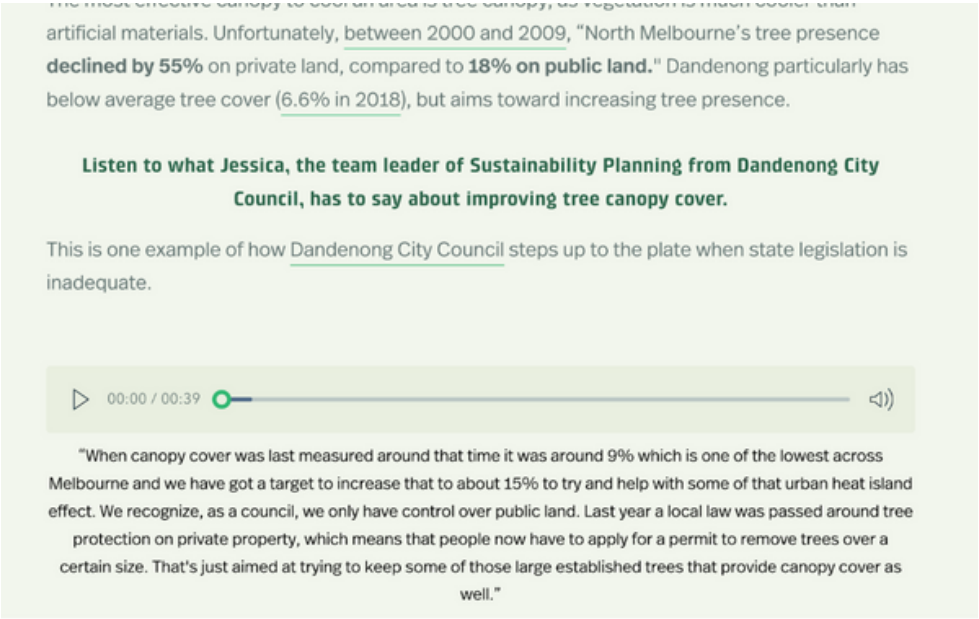

Figure 27: A screenshot showing some of the tree canopy coverage statistics and the use of the audio clip feature in StoryMaps to include a quote from Jessica.

Lastly, we concluded our StoryMap with a brief summary, leaving readers to think about what differences they want to see in the future to combat extreme heat. We hope that this StoryMap can show the public new perspectives on how extreme heat affects people. Additionally, bringing stories and real voices behind temperature data and research can hopefully convince legislators to act on these issues.

The public version of our StoryMap is owned by Sweltering Cities and is anticipated to be posted on their website. The version of our StoryMap that will not be edited by Sweltering Cities is only available to WPI students and faculty and can be found using the following link:

https://storymaps.arcgis.com/stories/9970b94372f64e07a74e03f4988e3fad.

Conclusion

Climate change affects Australia significantly, bringing heatwaves, droughts, and wildfires. In addition to climate change, the urban heat island generated by the Greater Melbourne area creates even higher temperatures. The urban heat island effects are projected to only worsen over the next several decades. We focused on telling the stories of four suburbs throughout the city this summer: Wyndham Vale, St. Albans, Broadmeadows, and Dandenong. Some of these suburbs were picked for having a low socioeconomic status, and others for significantly low tree canopy cover. In these four suburbs, we collected temperature data and recorded interviews to show how extreme heat impacts these communities. For each suburb, we developed a moral scheme based around our findings. Starting in Wyndham Vale, we showed how fake grass, lack of canopy cover, and dark roofs all contribute to the UHI effect. Then we moved east into St. Alban and explained how certain demographics, especially children, are vulnerable to extreme heat. In Broadmeadows, we investigated how extreme heat can affect daily routines, and in Dandenong we focused on how the local community is taking initiative in policy to make Melbourne safer. We gathered this powerful data and displayed it using ArcGIS StoryMaps, which allowed us to share the stories we collected in an engaging way. We utilized maps, video, audio, pictures, graphs, and text to share the voices of local community members in hopes to spread awareness and encourage action against the dangers of extreme heat. With further research and advocacy, the issue of extreme heat can be mitigated before it progresses beyond repair.

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Appendix A: Interview Question Bank

General Community Members

- How long have you lived in this area?
- What do you associate with high temperatures and hotter days?
- Do you rent or own a house?
- How do you keep your house cool?
- Tell me about your experience of heat in your community in the summer.
- Do you feel that heat poses a risk to your pet? How do you keep your pet(s) cool on hot days?
- How do you keep your kid(s) cool on hot days?
- Do you commute to work? Has the heat impacted your commute or decision to go to work?
- What do you associate with heat?

General Community Leaders

- How often do you notice members of the community walking on hot days?
- What are some materials or services you offer for community members who may be susceptible to the hot outdoor temperatures?
- What are your thoughts as to how well the issues caused by rising heat are currently addressed?
- How has your community/service been affected by heat?
- What do you think are the best ways to support efforts made to create cooler environments?

Medical Professionals

- What are the most common medical conditions caused by heat?
- Are you busier in the summer or in the winter? Do you think it is heat related?
- Are there any demographic groups that you treat the most for heat related illnesses?
- What do you think the city could do to reduce the amount of heat related illnesses?
- Is everyone that comes in able to be treated? (Do they have the money, are there long wait times etc.)
- Does your office get too hot, or is it sufficiently cooled?
- What are your recommendations to combat heat related illness?

Outdoor Workers

- How does the heat affect how much/what work you can do? How do you keep yourself and/or your workers safe during hot days?
- Do you feel that your working conditions properly accommodate higher temperatures? If not, how would you improve them?
- Have you ever lost work time due to heat related illness?
- Does the summer heat affect your income?

Additional Questions

- What work do you do regarding extreme temperatures in Melbourne?
- How have you noticed the climate patterns changing over the past decade or so?
- How has Banksia Gardens been affected by heat
- What are some existing policies regarding extreme heat?
- Tell me about your experience of heat while working at your cafe in the summer.
- What motivates you to volunteer for your community?
- Is there anything else you'd like to say concerning your experience in extreme heat?
- Why did you join the union?
- What efforts are you currently trying to pursue?
- What are the biggest issues you see?
- Do you think companies do enough to protect outdoor workers from the heat?
- Do you think the government is doing enough to protect outdoor workers?
- What jobs are most affected by heat stroke?

Appendix B: Interview Verbal Consent Script

Hello, we are four students from WPI, a college near Boston, working with a not for profit organization called Sweltering Cities. Our goal is to use storytelling and temperature data to spread awareness about how extreme heat affects Melbourne residents, specifically in four hot suburbs. We will use data collected from this interview to produce a report onto the Sweltering Cities website that will be publicly distributed. We want to include videos, voice recordings, and quotes, in addition to geographical temperature data. We will collect your first name or, if you are a medical professional and community leader, your professional name. Your participation is entirely voluntary. You can stop at any time, or refuse to answer any question.

Appendix C: Existing Policies on Extreme Heat

Rising temperatures resulting from climate change have prompted different levels of policies across the globe. In the United States, the Occupational Safety and Health Administration (OSHA) is proposing Heat Injury and Illness Prevention in Outdoor and Indoor Work Settings, a standard under the Small Business Regulatory Enforcement Fairness Act, (SBREFA) (Occupational Safety and Health Administration, 2022). SBREFA is meant to create a heat-specific workplace standard that holds employers accountable for protecting employees from hazardous temperatures.

Australia has national guidelines to mitigate heat effects. For example, the Australian Government published the National Climate Resilience and Adaptation Strategy in 2021 (Department of Climate Change, Energy, the Environment and Water, 2022). This strategy implements three primary objectives that aim to improve Australia's adaptation to climate change. These primary objectives are to drive investments towards global protection projects through collaboration, improve the output of climate change data and education, and assess progress in mitigating the effects towards climate change. For all of Southern Australia, employers are responsible for determining when it is too hot to keep working (SafeWork SA, 2023). SafeWork South Australia outlines the symptoms that employers should look out for in determining safe working conditions. The signs include reduced concentration, nausea, vomiting, and sunburns. SafeWork also outlines ways for employers to create safer working environments by providing cooling, hydration, proper attire, and medical checks.

Efforts are being made to mitigate the effects of heatwaves by the state of Victoria, but they vary between their municipal governments (Bolitho & Miller, 2017). For example, in the Moira Shire Municipality, the 2019 Municipal Heatwave Plan was developed (Moira Shire Council, 2019). This plan initiates emergency plans and increases access to health providers for groups of people who are most vulnerable to heatwaves. Meanwhile, the Mitchell Shire Municipal created the Mitchell Shire Council Environment Policy in May 2020 (Mitchell Shire Council, 2020). The Mitchell Shire Council Environment Policy focuses on the prevention of rising temperatures through controlled emissions and net-zero goals rather than emergency procedures.

Melbourne has pushed several forms of policies and action plans to counter the effects and causes of rising temperatures. Melbourne’s commitment to sustainability has made it a leader in environmental efforts (Go West Tours, 2023). The efforts that Melbourne focuses on include sustainably-powered public transportation, renewable energy sources for the city, net-zero buildings, green spaces, and sustainable food production.