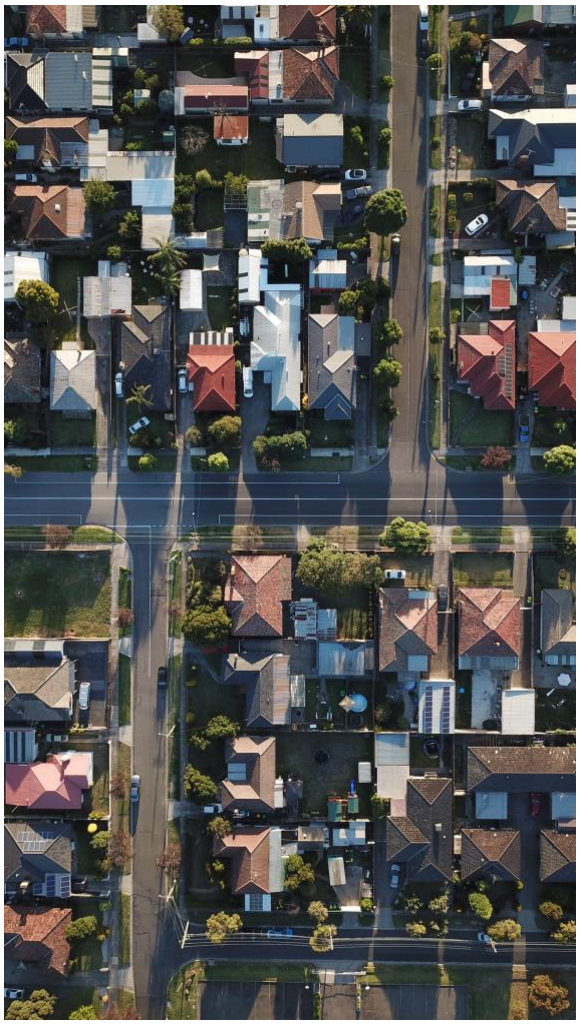

BUILDING HEAT RESILLIENCE IN RENTAL HOMES

ABSTRACT

We are already seeing the negative effects of climate change and extreme climate events. However, they are disproportionately affecting certain communities. It is essential that the different qualities and environments in which make people more vulnerable are identified and addressed. This research aims to identify how renters are vulnerable to heat-related illness and death due to the physiological, social, and environmental conditions of living in a rental home. Throughout the capstone, the factors which increase heat risk were identified, compared to the conditions of a renter, and simple solutions for how renters can build heat resiliency in a cost effective and simple way were proposed.

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Table of Contents

Introduction

Climate change is an issue that is becoming ever more pressing as we move into the future. The threat of extreme weather events and increased temperatures are affecting the balance of the ecosystem, health of human population, and all other living organisms. As temperatures become more extreme, it is disproportionately affecting certain populations. There are many factors which increase the risk of heat exposure, heat-related illnesses, and in extreme cases, death. In the United States there are an estimated 1,300 deaths per year as a consequence of exposure to extreme heat and an additional 600 deaths per year that are caused by underlying and contributing causes related to heat exposure (US EPA, 2016).

Low-income and minority populations have been identified as the most vulnerable populations due to physiological characteristics, location, and income. The physiological conditions such as being elderly, a child, pregnant woman, or someone with underlying diseases or illnesses increase the chances of suffering from heat-related illnesses or death. Social and economic factors increase risk for populations that are low-income, outdoor workers, homeless, or indigenous and Black, which face heat exposure more often than other groups (Roller, 2021). The built environment also has an influence on associated risk. Heat risk and exposure increase with location, access, and infrastructure. The factors vary across different ages, races, and financial status. Many of the factors mentioned, physiological, social, and economic, are common among low-income population and minorities (Simons, 2022). However, there is no evidence that suggests how being a renter alone increases heat risk and associated vulnerability.

Over one third of households living in the United States are renters, and the most likely populations to be renters are lower-income and minority households (Spader & Herbert, 2017). This information connects the two most at risk demographics with rental households. However, it is not indicated how being a renter increases risk outside of the other physiological, and social conditions of these populations that increase risk. This research aims to identify how being a renter alone, increases risk of heat exposure, what factors of the built environment increases risk, and how does cost affect the usage of cooling systems in rental homes.

Research Questions and Objectives

This research aims to identify the characteristics of a renter and rental property that increase vulnerability to climate change. The type of property management and elements of the built environment are also identified in relation to rental housing and vulnerability. The goal is to propose mitigation strategies for renters that are temporary and affordable to increase safety based on findings from a questionnaire distributed to renters in Tucson, Arizona. This research aims to answer the two following questions.

- **Does living in a rental household increase risk of heat exposure?**
- **What are the heat risk factors associated with living in a rental home?**

Literature Review

As the issue of climate change becomes more relevant in our daily lives, many researchers, students, governmental officials, architects, and urban planners have been looking into ways in which we can mitigate the effects of the changing climate. There are many pre-existing conditions that can make one more vulnerable to heat-related risk. This literature review will cover various risk factors and how they related to being a renter. It will also explore the risk associated with living in an urbanized area like the City of Tucson. Contributing to this literature review are the findings from "Disproportional Heat Exposure: Low-income and Minorities" (Simons, 2022), an unpublished manuscript by the author. This additional research analysis was conducted for the Climate Action Planning course at The University of Arizona as supplementary material for the Sustainable Built Environments Senior Capstone.

The City of Tucson is a high-density urbanized area, one where the urban heat island effect exists. The urban heat island effect increases temperatures within these areas due to lack of shading, increased traffic, and a high percentage of paved surfaces. It can also increase the risk and severity of heatwaves. Within a dense urbanized area, the temperature can reach up to 1-7°F warmer during the day and 2-5°F warmer at night than the surrounding suburban areas with low density housing, increased shade infrastructure and green space (US EPA, 2014). Heat risk increases in areas that lack shade infrastructure, are far more spatially dense, and are more densely populated. Surfaces covered in shade can be 20-45°F cooler than surfaces exposed to sunlight (*Using Trees and*

Vegetation to Reduce Heat Islands | US EPA, 2021). Plants providing shade also provide cooling through a process known as evapotranspiration in which water particles evaporate from the plants leaves. Spatially, rental properties are typically multistory facilities and are often poorly maintained by a larger property management company. In areas with high density buildings and multi-story complexes, there lacks proper ventilation due to the density not allowing for wind movement on the ground surface. Building materials can also increase temperatures by absorbing the heat rather than reflecting it, making buildings large thermal masses. Dark surfaces such as roofs and pavement absorb heat and warm the air around them, and on a high temperature day, surfaces can reach up to 60°F hotter than the ambient air temperature (US EPA, 2014). The high population density further increases the urban heat island effect due to the increase in human activity that produce heat and greenhouse gases. These activities include using electricity, transportation and travel, and industrial facilities that produce heat as a byproduct and/or waste product (US EPA, 2014) (Simons, 2022).

The built environment can be designed to mitigate the effects of heat exposure and extreme heat events. For renters in an urbanized area like Tucson, this adaption could simply be an air conditioning system within a home. On larger scale, adaption of green building practices and increased vegetation can cool a rental home. The issue with certain mitigation strategies is that many of these adaptions in the built environment are not possible for renters due to the cost and limitations in rental agreements.

Access to an air conditioning system has a direct impact on the mortality of people during extreme heat events. From 1980 to 1985, heat-related deaths among people with access to central air conditioning was 42% less than those without air conditioning. (O'Neill, 2005). Lack of access to air conditioning is due to a variety of sociological factors including mobility, employment, sociability, and affordability of electricity (O'Neill, 2005). One of the most common factors is the cost of an air conditioning system or a home with one already installed. Rental households may not have a proper cooling system that works or is well-maintained by the property owner or property management company. For a resident renting a home or apartment, there is no financial incentive to install an air conditioning system. The cost of installation, electricity, and maintenance come at a high price that may cannot afford in addition to their basic living expenses.

The cost of energy influences energy usage in most homes. Implemented in many urbanized areas are peak energy hours, where the cost of energy rises due to the increase in demand. During these peak hours utility companies charge a premium to deter customers from consuming in an attempt to reduce the energy demand on the grid. In emergency situations and extreme heat events, these peak hours can severely influence a residents energy usage for cooling, and result in the increase of heat exposure within homes (Simons, 2022).

Renters also face the issue of not having access to proper maintenance for the households' cooling systems. As climate change continues, so will the number of high-temperature days. By 2050, the number of heatwaves are projected to increase by 5 to 10 times, and is estimated to cause and additional 38,000 deaths in 2030 (Berry & Richardson, 2016). During heatwaves, energy is in high demand due to the amount of cooling systems in use at one time. Running a cooling system for long periods of time can put wear on the system, causing them to run inefficiently or even break down. Without a proper maintenance system in place, it can prolong exposure to high temperatures the longer it takes to get the cooling system repaired.

The concept of the landlord/tenant dilemma was also explored in relation to this issue. The landlord/tenant dilemma can be defined as when the interests of landlord and tenants do not align, which creates a barrier that hinders progress (Ástmarsson, Jensen & Maslesa, 2013). Certain policies can either create a gap between the landlord and tenant or a better relationship; it's all about finding a balance and/or policy that can diminish the landlord/tenant dilemma. Policy that includes a monetary incentive for landlords to make updates to their rental properties was discovered to be one of the more successful types of policy. Monetary benefits include tax incentives, rebates, and cost of energy savings. For a renter looking to live in a well-maintained and safe dwelling, policies like these can help in persuading their landlord to make upgrades to their homes and better maintain them to ensure the safety of the renter.

Many mitigation strategies to combat heat effects are in close relation to sustainable living and/or housing. This topic is becoming more relevant as we talk about the ways in which we can ensure safety and resiliency in the coming years with climate change. The research from "An empirical study on the energy consumption in residential buildings after adopting green building standards"

and "Energy efficiency and economic value in affordable housing" determined that there are large savings that come with adopting green building standards and making sustainable updates. In one case, there was a 43.7% cost savings in the green buildings in comparison to the state average of Virginia (Zhao, McCoy, & Du, 2016). These statistics were partially dependent on tenant behavior including frequency of appliance usage, setting of thermostats, as well as the time of year. Behavior is something that can easily be changed by education of the building systems and overall usage. Working collaboratively with a landlord, a renter can change or monitor behaviors in order to save on utilities (Zhao, McCoy, & Du, 2016). It is not indicated how this translates to the price of rental properties; however, it can be managed by the implementation of price stabilization policies following policies to increase sustainable housing to ensure that no one is displaced due to rent increases (Chegut, Eichholtz, & Holtermans, 2016). A change in policy like this can increase standards across rental housing without resulting in drastic changes in rental pricing.

Methodology

This research study analyzes qualitative data. Qualitative data allows for more open-ended personalized answers to get to the root of the issues regarding heat resiliency in rental properties and the type of people that rent. To collect qualitative data, a survey was created and distributed to renters that live within roughly a 1-mile radius of The University of Arizona campus. The survey was a questionnaire asking people to answer questions about their living situation, personal opinions, quality of maintenance, as well as their likelihood of making changes to their home. Each question was designed carefully so that the data could then be collected and analyzed in a quantitative analysis to show percentages and support findings.

The survey was created using The University of Arizona Qualtrics account. Qualtrics is a survey account that does all the mathematics and computing of data automatically when a survey is completed. This way, all the surveys could be taken electronically and distributed over the internet to more people. There was also no delay between the time the survey was completed and when the results could be viewed; all answers were uploaded to the Qualtrics database immediately and could be viewed in real-time. The other research method used was literature reviews. Literature reviews identified policies that related to climate action planning, heat mitigation strategies, potential policies, and how policies affect the topic. Through literature review and policy review,

the process of policy making as well as which policies will best provide context to the research were further understood. Research on policy is extremely important to answer the research question. The examination of policies implemented in other locations was also proven helpful in choosing the right strategies for Tucson.

I. Study Area

The study site selected was Tucson, Arizona, more specifically about a 1-mile radius around The University of Arizona shown in Image 1.0. The areas are between West to East roads, Grant and Broadway, and North to South roads, Stone and Country Club. This is an area where there is a higher number of rental properties due to the college student demographic of the area. It was also important that information was gathered from people that rent from a property management company as well as directly from the property owner [landlord] so that the policy findings could focus on what is needed most for the city of Tucson. Around The University of Arizona, there is a good mix of properties being rented by property management companies as well as privately by property owners.

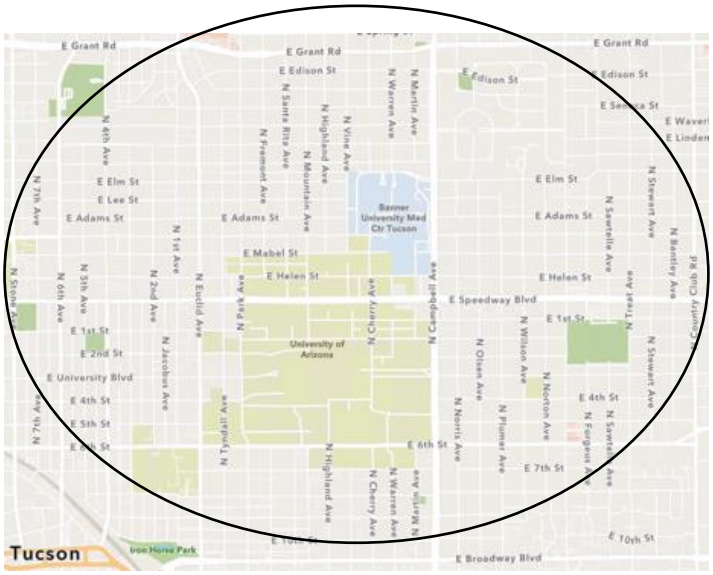


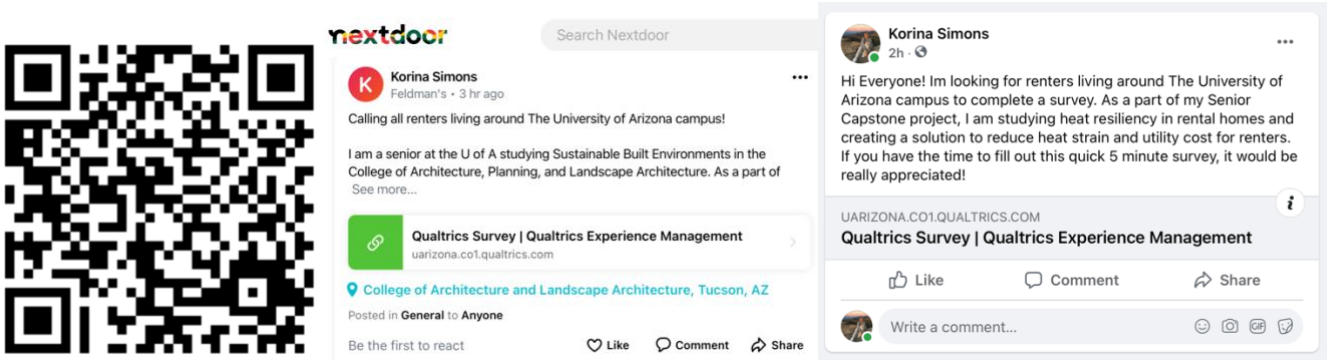
Image 1.0 – Map of surveyed area

II. Data Measures

The data used in this study are both primary and secondary data. Using the survey, primary data will be collected straight from the source, the renters. This data will be new data collected by the surveys and analyzed. The other type of data being used in this study is secondary data. The secondary data comes from the literature reviews as well as governmental institutions, where I will be able to research policy that already exists in relation climate action planning/heat mitigation for rental homes.

III. Methods

To gather data, the survey was distributed in many ways. The survey was also distributed via QR Code shown in Image 1.1. Using the QR Code that was specially made for the survey by Qualtrics, a flyer was created. Five copies of this flyer were printed out and distributed around The University Campus on various billboards and posts. These locations included The Student Union, the Main Library and the Science and Engineering Library. The most effective way of distribution was posting the survey link, along with a message through the Nextdoor app shown in Image 1.2. This app connects people with neighbors in various neighborhoods of the community of Tucson. The survey was posted to the Feldman's, West University, and North University neighborhood



Images 1.1, 1.2 and 1.3 – Depicting ways in which survey was distributed

discussion pages as well as the Safety page that is accessible to all members of Nextdoor in the Tucson area. The message was also posted to various Facebook Groups that related to The University of Arizona and/or rental properties, shown in Image 1.3. Some of the Facebook Groups included University of Arizona Housing, Sustainable Tucson, and University of Arizona Class of 2022. At the end of the survey, respondents were asked to send the survey to other people in an attempt to snowball sample and reach a larger audience. This was proven successful in only a few cases.

Results

A pilot study was conducted, and the results were in the format of qualitative data from a survey. There was a total of 50 survey respondents. The survey results have then been turned into quantitative data to be represented in various ways. The first part of the results are findings in relation to physical attributes and objects of the survey respondents. This includes type of housing,

who/what they rent from, and sustainable features of their home. The second section of the results are more physiological findings about the respondents including willingness to made changes to their home, comfortability of their home, and how heat affects them. Dividing the findings into two sections allows for an analysis of the two different aspects of the survey questions.

By the process of distributing the survey to a target population, and asking that only renters respond to the survey, 100% of respondents were renters. This was determined by the first survey question, in order to eliminate responses from property owners. A density map was used to identify the location of respondents shown in Image 1.4. All respondents were within the targeted area due to the strategies of distribution of the survey.

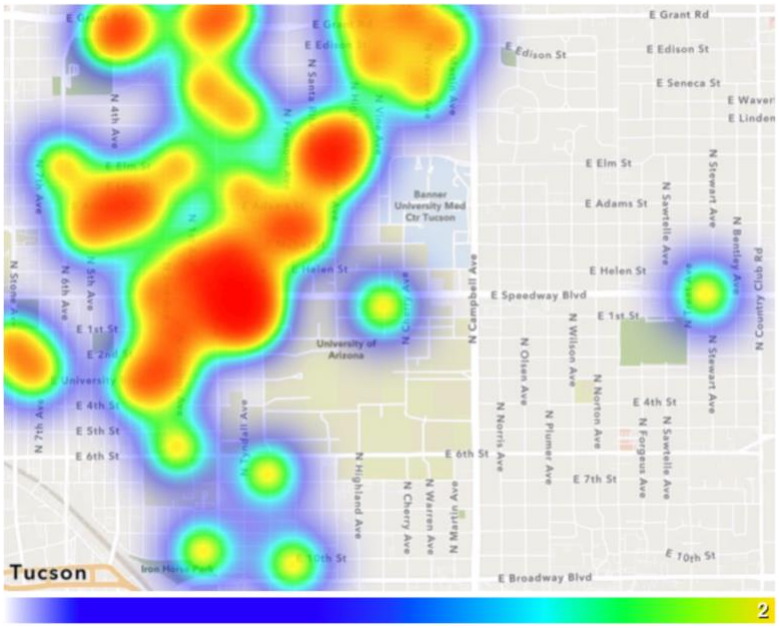


Image 1.4 – Density map of respondents' location

The density map indicates that most respondents reside in the West University, Feldman's and North University neighborhoods, at the northwest side of campus. It can be suggested that the location of respondents favored this area due to the distribution of the survey through Nextdoor, where the survey was posted to the Feldman's neighborhood chat. Within these locations are a variety of homes. The types of homes are represented in the pie chart below. This has significance as it can provide information about the type of resources the renters may have available to combat heat, as well as the proximity of their neighbors.

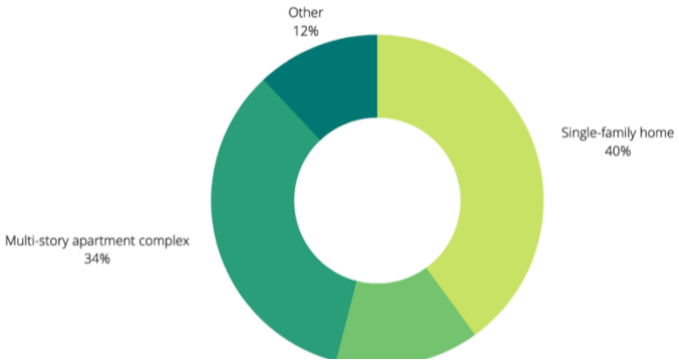


Image 1.6 – Type of residential homes of respondents

Of these respondents, 36% rent directly from the landlord/property owner, and 64% lease from a property management company shown in Image 1.6. This first set of

information provides insight on the validity of possible solutions and strategies to be implemented. Existing cooling systems in the home were also surveyed. It was possible to choose multiple options of cooling systems, as many have a variety of cooling systems. 37 of the 50 respondents have central air conditioning in their home, 8 homes have swamp coolers/evaporative coolers, 7 homes have window AC units, 4 have ductless mini split units, and 17 of the homes have fans.

Respondents were asked about the quality of maintenance of their home. It was discovered that 33 out of 50 respondents had a reliable maintenance system in case of an emergency, which was described as a 24-hour turnaround from the time maintenance was requested to the time of resolution. Typical maintenance was found to be resolved in a timeframe that averaged around 4 days, with renters waiting as long as 2 to 3 weeks for issues to be resolved and as short at 24 hours. The longer maintenance takes to resolve issues, the more at-risk a renter can be to heat exposure. When asked what cardinal directions their windows face, the results are identified in Table 1.0

Table 1.0 – Direction of windows

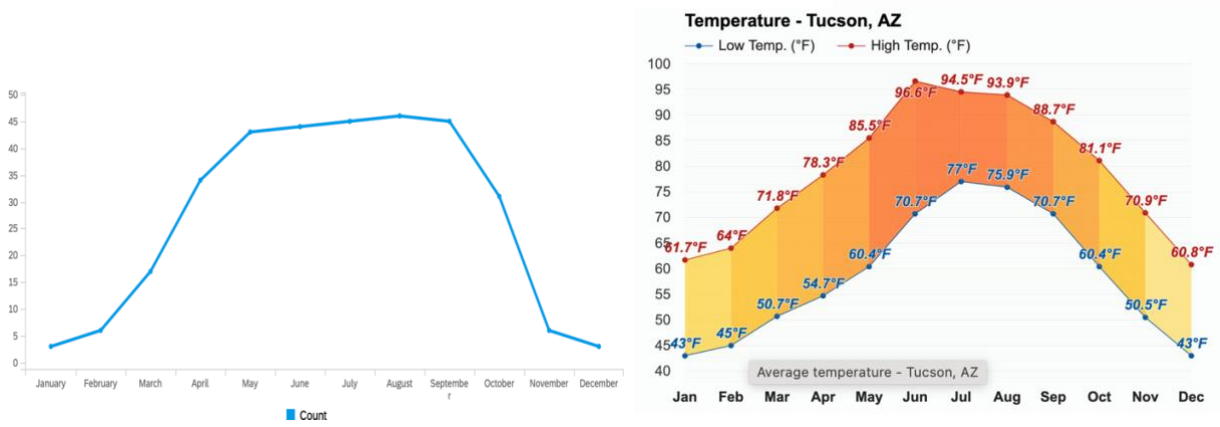
Cardinal direction	Number of respondents (out of 50)
North	27
East	24
South	28
West	27
I am unsure	3

This information shows that most respondents have North, South, and West facing windows. In the Northern Hemisphere, South-facing and West-facing windows receive the most direct sunlight during Summer and Winter months. East and North-facing windows receive the weakest amount of sunlight and are cooler.

Respondents were then asked questions about the energy usage within their home, the cost, and other questions in relation to their personal habits. When asked what temperature the residents kept their house at, the average was discovered to be 73 degrees. It should be noted that two respondents identified two separate temperatures for winter and summer, varying 10 degrees in difference, and other outliers were removed from the calculation of the average. When asked about the months in

which they use the cooling system in their home, the information found was consistent with the average temperature of Tucson. There was a positive relationship between temperature and amount of people turning on their cooling system and number of people using a cooling system for comparison. Shown in Image 1.7.

Image 1. 7 – Energy usage compared to temperature curve



The cost correlates with the influx of energy usage during hotter months; however, respondents were only asked for the average cost of electricity month to month. On average, the respondents pay $116.23 a month on electricity. With the minimum of $32 and maximum of $240. It should be noted that respondents were not asked how many people reside in their home, therefor the data may be skewed by electricity bills that are split. However, this is close to the average electricity bill in Arizona at $128. When asked how much price influences the usage of cooling on a scale of 1 to 5 (where 1 is not at all, while 5 is a great deal), the average of the responses was 3.29. This means that the respondents amount of energy usage on cooling is influenced by cost. This information provides insight on how cost may influence the type of adaption strategies respondents are willing to pursue. When asked if the respondents have ever sought cooling from a community location, 15 out of 49 respondents said yes. This can lead to the assumption that most respondents have reliable access to a cooling system at their home.

In relation to ways in which renters could build heat resiliency in their home, they were asked a series of questions about mitigation and adaptation strategies to reduce heat in their home. These strategies were compiled after completing an extensive literature review on the topic. It was determined that these simple strategies would be best suited to the survey respondents due to the

fact that the respondents may not have a background in sustainability, and therefore would be unfamiliar with other complicated proposals. The strategies proposed were also cost friendly, effective, and mostly non-permanent to stay within agreements of a typical lease agreement. They were asked to rate the questions 1 – 5, where one is extremely unlikely and 5 is extremely likely. The results are depicted in the chart that follows.

Table 1.1 – Mitigation strategies and response

Strategy	**Average response rate**
Swap light bulbs for energy-efficient ones (emits less heat)	3.96
Plant shading trees and bushes	3.06
Install a shade cloth (outdoor)	3.46
Install tinted window film	3.17
Cook outdoors	2.65

The installation of energy efficient light bulbs was ranked most likely to adopt and ranked last was to cook outdoors. From this information it appears that respondents were more likely to adapt strategies that are commonly associated with cost savings, yet this is not conclusive due to the limit of strategies proposed.

Conclusion

This research represents a larger issue that is becoming more evident in today's society. Those who rent lack control over their property and therefore are more vulnerable to heat exposure. Renters are more at risk for heat exposure that can cause heat-related illness such as cardiovascular and respiratory diseases. Renters heavily rely on the landlord or property management company to maintain the property and ensure their safety. The survey concluded that those who rent from a property management company on average, wait longer for maintenance than those who rent directly from the property owner, their landlord. There exists the tenant/landlord dilemma where the wants and needs of a tenant do not align with that of the property owner. There is an even larger separation when the rental property is under management of a property management company, where there is very little to no contact between the property owner and the tenant. The type of home in which a renter lives also has an effect on the time it takes to receive maintenance. Those who lived in an apartment or casita with multiple rental homes on the same property

received maintenance faster than those who lived in a single-family home. It can be inferred that this is due to the increase of properties under management that are facilitated better than others. However, there is no evidence that conclusively supports this inference.

Energy cost also influenced renters' usage of their home's cooling system. This is an issue that is becoming more common as energy prices rise due to an increase in demand. Utility companies are implementing peak energy usage fees, where energy costs are higher during hours of high demand. These hours typically differ between Summer and Winter months, however, and are fully controlled by the utility companies. This can negatively influence renters that are experiencing financial issues, as they attempt to maintain a tight budget, the temperature in their home rises.

There was no evidence found in the survey that suggests that any of the respondents were in severe danger of heat exposure, however this data can be used to infer situational issues that may rise in a severe heat event such as a heatwave or city-wide blackout. In events like these, heat becomes an even more pressing issue, and for the City of Tucson, where temperatures are already typically high during the summer months, it could create a catastrophic event.

Recommendations

With this information I was able to suggest a few mitigation techniques that are cost-friendly and will provide the most appeal to the rental community. Survey respondents were asked on a scale how likely they were to adopt some simple changes to their home on their own. The most likely change that survey respondents would adopt was swapping incandescent bulbs to high-efficiency LED lightbulbs. This is a simple solution that not only has a direct energy cost reduction but can also reduce heat. Incandescent bulbs emit more heat than LED bulbs. The next recommendation that was favored by the respondents was installing a shade cloth outdoors. Shade cloths are used widely around the City of Tucson to provide extra shade in outdoor restaurant seating and personal homes. You can acquire these cheaply and are easy to install. This is partly why shade cloths were favorable amongst survey respondents. Tinted window film was also favorable as a cost-efficient way to reduce sunlight within a rental home. Tinted window film can be purchased at nearly any hardware store and is a temporary solution that will not affect the windows long-term. This solution also allows for increased privacy for those living along a heavily trafficked street or high-density

apartment complex. There are a variety of tinted window films available, depending on personal preference for lighting, color, and opacity. Although not highly ranked, planting shading plants is also recommended to decrease sun exposure outside of the home. This recommendation was limited to those who live in a single-family home or casita, since residents within apartments do not have a private greenspace where they would be able to do so. Cooking outdoors was favored last amongst the proposed implementations. Cooking outdoors, especially in the summer months in Tucson, is not popular due to already high temperatures outdoors.

Separately from the survey, it is recommended that renters get to know their neighbors and foster a positive relationship with their landlord and/or property management company. Social relationships lead to social resiliency within a community and a home. By creating a relationship with neighbors, it expands the resources available to the renter. A relationship with the property owner is essential for closing the gap between the tenant/landlord dilemma mentioned previously.

Apart from what the renter can do, I suggest that there be a change in public policy. As mentioned previously, there exists the tenant/landlord dilemma. This gap in communication may only be closed by fostering a relationship between the tenant and landlord, but this is not easy in most rental cases, especially those renting from a property management company that follows strict protocols and procedures in the management of property. I suggest that cities implement a rebate and/or incentive program for property owners to upgrade their property in a sustainable fashion. This may include a rebate for installing a new air conditioning system or increasing the amount of shading plants within the property to ensure safety of the renters, especially in a city like Tucson, Arizona that experiences temperatures exceeding 100°F for a large portion of the year. This temperature combined with the older and poorly maintained homes within the surveyed area increases risk of heat exposure. As homes and appliances get older and the days get warmer, the city will need to create policy so that the city remains safe during extreme heat events, especially renters that have little to no control over the maintenance of the property.

Limitations

There were a few limitations of this research. One of the limitations was the survey population being limited within a radius of a few miles around the University of Arizona. A majority of this

population represents students at the University of Arizona, therefore many of them are financially stable and not in a low-income area. I believe that if the survey was distributed to a low-income area like South Tucson, the results would be extremely different. Low-income and minority populations experience the effects of heat disproportionately to those of the high-income class. This was not represented in the survey as no questions regarding income, race, or gender were asked. In addition to this, the survey results could not provide a comparison of heat risk between renters and homeowners. It did not produce any evidence that could support the idea that renters face a higher risk of heat-related illness and exposure. It can only be inferred by the literature review that renters, who are commonly low-income, are also disproportionally affected by heat. However, there are a variety of physiological and sociological influences on low-income households, apart from being a renter, which make them a vulnerable population.

References

Ástmarsson, B., Jensen, P. A., & Maslesa, E. (2013). Sustainable renovation of residential buildings and the landlord/tenant dilemma. *Energy Policy, 63*, 355-362.

Berry, P., & Richardson, G. R. A. (2016). Approaches for Building Community Resilience to Extreme Heat. In S. L. Steinberg & W. A. Sprigg (Eds.), *Extreme Weather, Health, and Communities: Interdisciplinary Engagement Strategies* (pp. 351–388). Springer International Publishing. https://doi.org/10.1007/978-3-319-30626-1_15

Chegut, A., Eichholtz, P., & Holtermans, R. (2016). Energy efficiency and economic value in affordable housing. *Energy Policy*, *97*, 39-49.

O'Neill, M. S. (2005). Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence. *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, *82*(2), 191–197. https://doi.org/10.1093/jurban/jti043

Roller, A. (2021, September 13). Equity in Resilience: Addressing the unequal health impacts of extreme heat. *Center for Climate and Energy Solutions*. https://www.c2es.org/2021/09/equity-in-resilience-addressing-the-unequal-health-impacts-of-extreme-heat/

Simons, K. (2022). Disproportional Heat Exposure: Low-income and Minorities. Unpublished manuscript, The University of Arizona

Spader, J., & Herbert, C. (2017). America's Rental Housing 2017. *Joint Center for Housing Studies Harvard Univeristy*, 40.

US EPA, O. (2014, June 17). *Learn About Heat Islands* [Overviews and Factsheets]. https://www.epa.gov/heatislands/learn-about-heat-islands

US EPA, O. (2016, July 1). *Climate Change Indicators: Heat-Related Deaths* [Reports and Assessments]. https://www.epa.gov/climate-indicators/climate-change-indicators-heat-related-deaths

Using Trees and Vegetation to Reduce Heat Islands | US EPA. (2021). EPA United States Environmental Protection Agency. https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands

Zhao, D., McCoy, A., & Du, J. (2016). An empirical study on the energy consumption in residential buildings after adopting green building standards. Procedia Engineering, 145, 766-773.