CHALLENGES + RESPONSES TO THERMAL COMFORT + INDOOR AIR QUALITY FOR MULTI-FAMILY HOUSING IN THE FACE OF INCREASED EXTREME HEAT EVENTS + WILDFIRES AMIDST ANTHROPOGENIC GLOBAL CLIMATE CHANGE

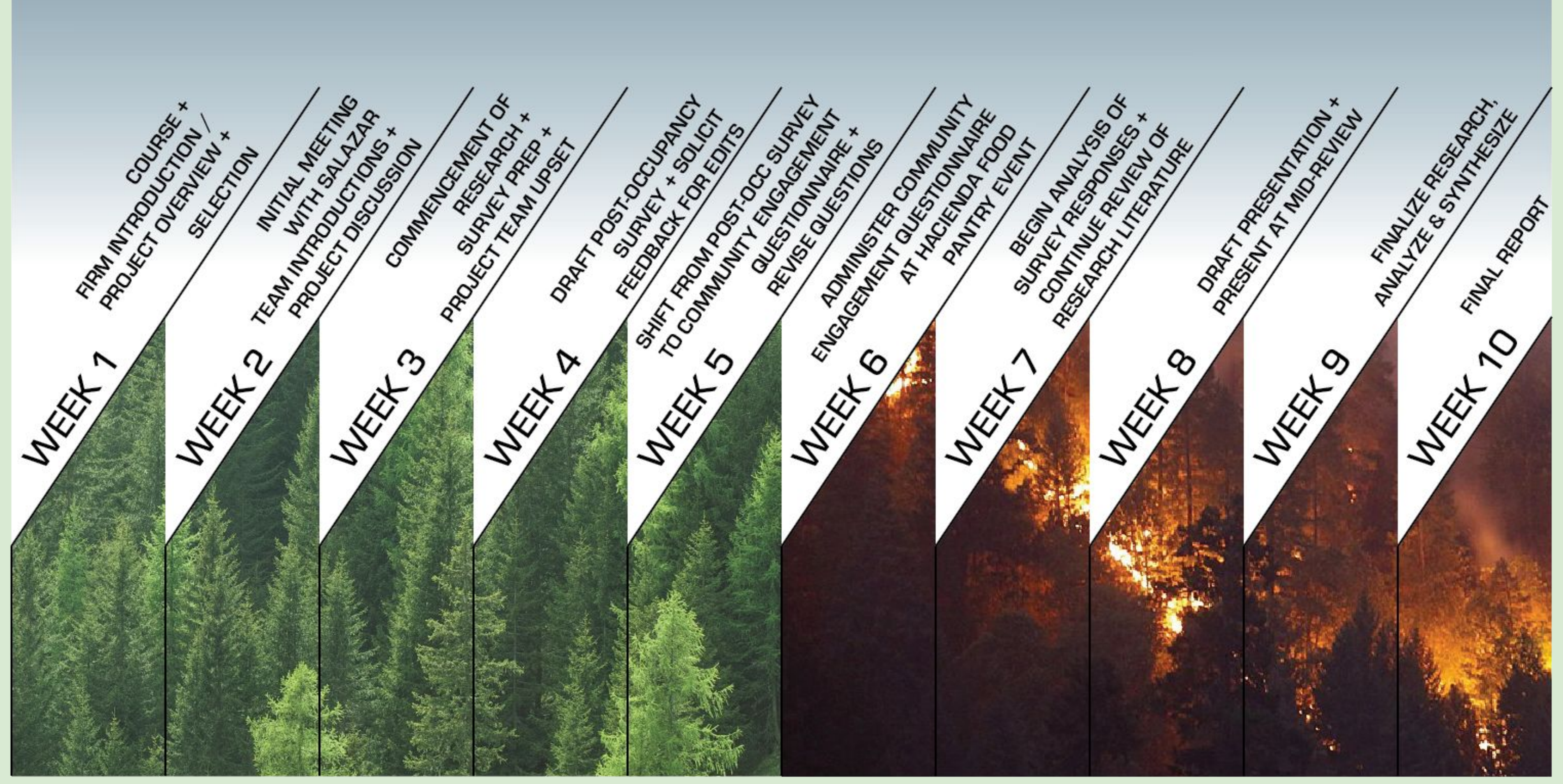
ABSTRACT

This research sought to investigate the perceived occupant comfort levels given the reality of global climate change and the increasing occurrence of extreme weather events. The research conducted was two-fold. First, a community engagement questionnaire was developed and administered to solicit qualitative feedback from community members. Simultaneously, scientific literature was researched and reviewed surrounding specifically identified events related to changing climate conditions: extreme heat events (EHEs) and wildfires (WF).

Heat is the leading cause of weather-related mortality in the United States. EHEs are categorized as summertime weather that is substantially hotter and/or more humid than average for a location at that time of year. With 100% relative humidity, the upper threshold for humans is a wet bulb temperature of 95°F. Above this temperature, humans begin to experience hyperthermia, which can lead to heat exhaustion, heat stroke, and death. In this research, phase change materials (PCMs) were identified as a probable avenue of further research into responses to EHEs.

Wildfires pose a particular risk to buildings located in the Wildland-Urban-Interface (WUI). While the greatest threat from wildfires to building structures occurs in rural and suburban WUI areas, adjacent urban areas are susceptible to hazardous air quality from smoke. Resilient design strategies including structure hardening and the creation of defensible space may be advantageous in WUI areas. However, a more urgent urban and multi-family housing priority may be the protection of indoor air quality for building occupants.

PROJECT TIMELINE



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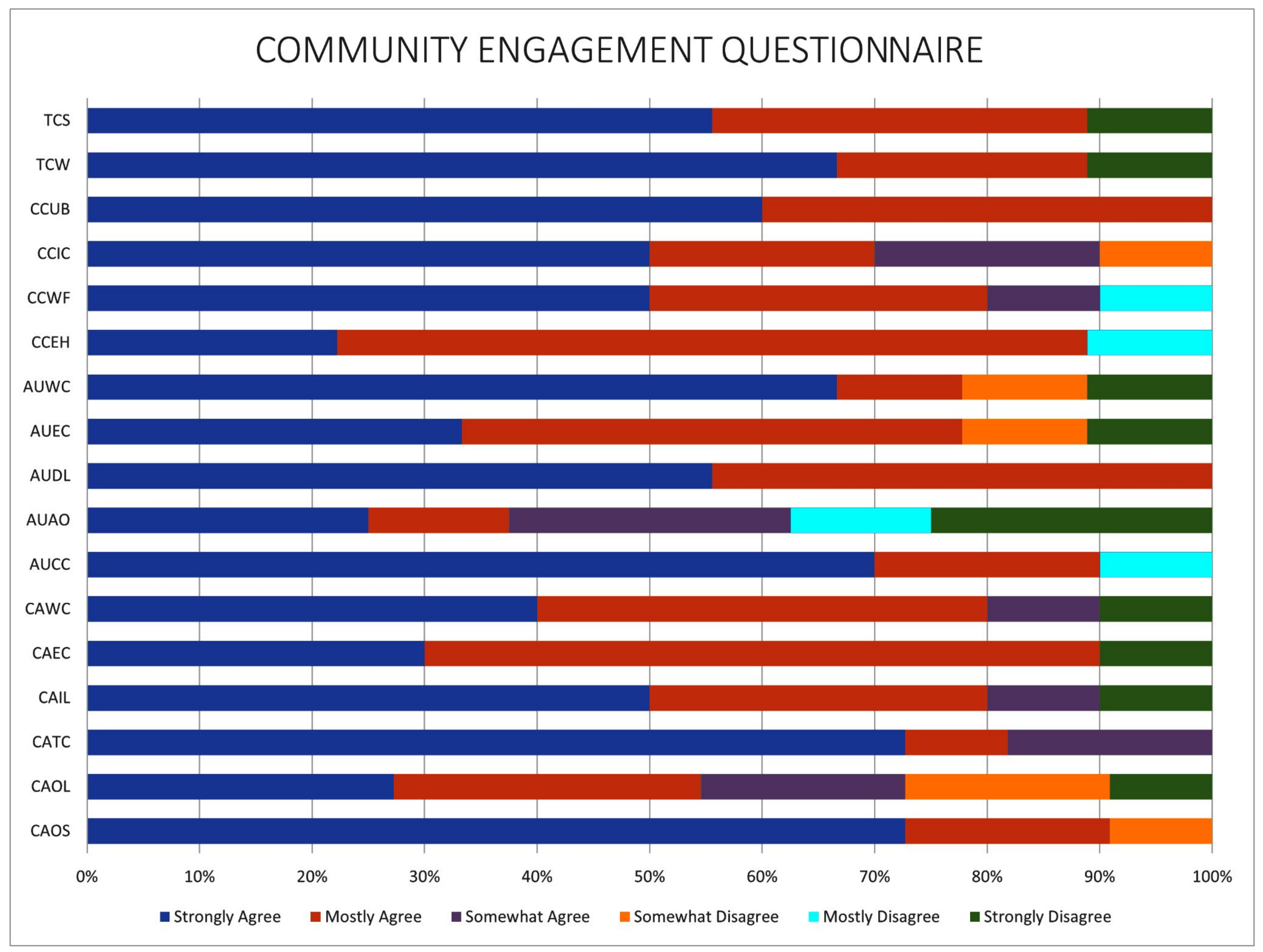
PROCESS

The research was conducted in three phases:

Phase One
1. Develop, refine and administer Community Engagement Questionnaire.
2. Initial research of EHEs and identification of associated challenges.
3. Initial research of WFs and identification of associated challenges.

Phase Two
1. Review and interpret qualitative community responses and use as a lens through which to inform focused research.
2. Narrow focus of EHEs specifically to issues of thermal comfort and identify strategies.
3. Narrow focus of WFs specifically to issues of indoor air quality and identify strategies.

Phase Three
1. Compile findings and make appropriate recommendations.
2. Identify limitations and make future suggestions.



TCS	I prefer a cooler summertime thermostat setpoint.
TCW	I prefer a cooler wintertime thermostat setpoint.
CCUB	I am concerned about how global CC might affect my utility bills.
CCIC	I am more concerned about global CC in the wake of recent EHEs and WF.
CCWF	I am concerned about how increasing WF will affect my household air quality.
CCEH	I am concerned about how increasing EHEs will affect my health and safety at home.
AUWC	Despite the WF last summer, I did not experience significant smoke-related respiratory discomfort in my apartment home.
AUEC	Despite the EHEs last summer, I was able to maintain my comfort within my apartment home, even if running the A/C more.
AUDL	On a typical spring or summer day, there is usually enough daylight in my apartment to leave my artificial lights switched off.
AUAO	I notice my apartment becoming uncomfortably warm in the late afternoon.
AUCC	The climate controls in my apartment home are easy to understand and operate.
CAWC	Despite the WF last summer, I did not experience significant smoke-related respiratory discomfort in indoor common areas.
CAEC	Despite the EHEs last summer, the temperature in indoor common areas remained comfortable.
CAIL	When enjoying my community's indoor common areas, I can almost always find plenty of light for my needs.
CATC	The temperature in indoor common areas is usually quite comfortable.
CAOL	The lighting in outdoor common areas is adequate for my nighttime needs.
CAOS	When enjoying my community's outdoor common areas, there are plenty of places in the shade on a hot summer day.

FINDINGS

EHE - Mortality from all causes spikes in cities by 7–14% on extremely hot days. The mortality effect of heat-waves was stronger among the elderly, with the highest increase in mortality among those over 75. The effect was also larger among females than males. Low-income areas may be disproportionately impacted by EHEs due to high crime rates and fear of taking appropriate action, such as opening windows. Urban heat islands contribute an additional 13% of cooling loads onto the typical urban building.

In a case study of 70 multi-family social housing units in Toronto, every unit experienced a high prevalence of discomfort from heat in summer, and some units experienced temperatures above 82°F for extended periods. One study estimated that residential electricity bills will increase by 15–30% to pay for the increase in air conditioning, necessitated by global climate change.

The results of one study indicated that the use of PCM wallboards on the internal surfaces of a building can significantly reduce the cooling loads. The annual cooling demand of an entire house was reduced in the presence of PCM boards, which led to an annual 29% savings on energy consumption. For specific months, the PCM boards could reduce most or all the cooling demand of a building. PCMs, combined with proper ventilation, can reduce the severe discomfort period of EHEs by 65%.

Green roofs improve human thermal comfort by reducing the heat index by up to 2.7°F for pedestrians and 10.3°F for roof surface levels, while cool roofs reduce the heat index by up to 4.3°F for pedestrians, and 14.4°F for roof surface levels. With lower upfront and life-cycle costs than green roofs, cool roofs offer significant value.

Tree shade can reduce surface temperatures by up to 35°F and ambient air temperatures by up to 9°F. Heat index assumes shade; actual heat index can be up to 15°F higher in direct sunlight.

WF - Occupant health is directly linked to the preservation of indoor air quality. In the United States, as many as 8,500 hospital admissions are made annually for respiratory symptoms due to wildfire smoke inhalation. According to the EPA, most home HVAC systems utilize 1" thick, low efficiency, air filters with a Minimum Efficiency Reporting Value (MERV) of 1-4. Proper installation and operation of MERV 13 filters is one method of preserving indoor air quality levels during wildfires. According to the EPA, MERV 13-16 filters can remove up to 95% of particles that pass through it, including smoke particles.

Designing with passive-house strategies to tighten the building envelope can reduce the infiltration of unwanted and unfiltered air. This strategy aids in taking the burden off of occupants to ensure the appropriate air filters are installed and operational.

CONCLUSIONS

Buildings integrated with PCMs reduce heat stress during EHEs. The use of PCM wallboard with the appropriate phase change transition temperature is crucial and dependent on the climatic conditions; the incorporation of PCM26 produced a 16% reduction of annual cooling loads, compared to 29% reduction produced by PCM24. Every effort should be made to minimize ozone and airborne particulates during EHEs. Cool roofs have a significant value advantage over green roofs for low-income multi-family housing. Strategies to adapt to heat, like tree shading or natural ventilation, may conflict with strategies to adapt to wildfires.

Although healthy indoor air quality may be achieved by installing MERV 13 filters, they require HVAC systems to be running, placing an expense on occupants. Designing to reduce air infiltration may help alleviate individual occupant expenses.