SMART GROWTH AND REGIONAL COLLABORATION

Housing Pathway
MMC Heat Preparedness Plan Heat Health Research Brief

Social determinants of health are the conditions in which people live that affect a wide range of health risks and outcomes. Our social context, economic situation, and built environment can buffer climate impacts by providing us a means to cope or adapt. They can also amplify climate impacts, especially among communities that have been subjected to structural racism and other inequities. MAPC identified six social determinant pathways through which people experience climate-driven extreme heat impacts. For each pathway, MAPC conducted a brief literature review and summarized the findings into a short memo.

Key Insights

- Most heat-fatalities occur within people's homes, but few studies focus specifically on indoor heat exposures. There is also limited observational data on indoor heat conditions, and outdoor temperature has proven an inconsistent indicator of temperatures indoors.
- Continuous exposure to high temperatures can lead to heat-related illness, pregnancy-related complications, worsening of heat-sensitive mental and chronic health conditions, and death. Even short periods can affect cognitive functioning, sleep, and thermal comfort.
- Risk factors for indoor heat exposure include poor access to indoor cooling, high energy cost burdens, occupant behavior, lack of enforceable (or evidence-based) temperature standards, building characteristics, and location.
- High energy bills resulting from increased air conditioning (AC) usage put households at risk for high energy cost burdens[1], which can lead to utility arrearages and shutoffs for non-payment of utility bills. Many households ration indoor cooling and maintain their homes at unsafe temperatures to compensate for high energy costs.
- Several studies found that certain efficiency measures may inadvertently increase indoor heat exposure by diminishing nocturnal heat loss, especially if inadequate night-time ventilation is provided. More research is needed to understand specifically how energy efficiency measures, alongside other building characteristics, influence both energy consumption and heat resilience in our local context.

Recommendations

- Increase knowledge building of residential heat risks and coping strategies (esp. among more sensitive populations)

[1] Energy burden is defined as the percentage of gross household income spent on energy costs. Households that allocate more than 10% of their gross income for energy expenses are considered energy cost burdened.

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- Improve access to affordable, energy-efficient indoor cooling solutions that do not increase energy burdens and improve access to AC as interim strategy
- Adapt federal, state, and local programs that address energy insecurity and residential energy efficiency to better meet the needs of low-income, renter households and future climate conditions (less need for winter heating vs. greater need for summer cooling).
- Expand research on thermal comfort thresholds and implement tenant protections to ensure safe habitation during the summer cooling season.

Research Summary

Connections Between Health and Housing

Housing is among the most well understood social determinant of health, with a strong evidence base demonstrating its impact on both health outcomes and healthcare spending. Housing primarily influences health through four pathways: quality, stability, affordability, and neighborhood characteristics.[2] Each of these pathways mediates people's experiences with climate-driven heat. Sub-standard housing conditions perpetuate poor health outcomes in a variety of ways – exposure to pests, pollutants, injury risks, and extreme temperatures. Most housing also lacks even the most basic accessibility features for people with impaired mobility. People who experience homelessness or who are unstably housed[3] are more likely to experience poor health and disruptions to care, school, and employment. Energy costs from operating indoor cooling can also contribute to housing cost burdens. Most standard definitions of housing affordability say that housing costs, inclusive of utility expenses should make up no more than 30% of a household's income. According to 2015 figures, nearly a third of US households struggle to pay their energy bills and one in five households reduces spending on food, medicine, and other necessities to pay an energy bill.[4] Low-income households and people of color are also more likely to live in urban heat islands (UHI), neighborhoods with few trees or green spaces and large areas of pavement that absorb and slowly re-emit heat.[5]

Health Impacts of Exposure to Heat at Home

Most Americans spend 80-90% of their time indoors, and an estimated two-thirds of that time is spent inside their home. Few studies focus specifically on the health effects of home heat

[2] Taylor, L. (2018). Housing and Health: An Overview of the Literature. Health Affairs. https://www.healthaffairs.org/do/10.1377/hpb20180313.396577/full/

[3] Housing instability is variably defined as having difficulty paying rent, spending more than 50% of household income on housing, having frequent moves, living in overcrowded conditions, or doubling up with friends and relatives.

[4] Barry, C., Hronis, C., Woodward, M. (2015). Residential Energy Consumption Survey. United Stated Energy Information Administration. As reported by WBUR: https://www.wbur.org/npr/649633468/31-percent-of-u-s-households-have-trouble-paying-energy-bills

[5] Jesdale, B.M., Morello-Frosch, R., Cushing, L. (2013). The Racial/Ethnic Distribution of Heat Risk-Related Land Cover in Relation to Residential Segregation. Environmental Health Perspectives. 121, 7.

exposures even though most heat-related fatalities occur in people's homes.[6] Studies frequently generalize impacts across both outdoor and indoor environments. There is also limited observational data on indoor heat conditions, and outdoor temperature has proven an inconsistent indicator of temperatures indoors.[7] Despite these limitations, researchers have established that indoor environments can worsen and prolong exposure to high temperatures in several ways. Longer, more intense heat events result in greater increases in indoor temperatures. Indoor temperatures can rise progressively over consecutive days and over the course of the summer, exposing occupants to sustained heat. While outdoor temperatures typically decrease from peak daytime levels overnight, temperatures indoors tend to remain elevated.

Continuous exposure to high temperatures can lead to heat-related illness, pregnancy-related complications, worsening of heat-sensitive mental and chronic health conditions, and death.[8] Even short periods can affect cognitive functioning, sleep, and thermal comfort. Sleep-related impacts, such as frequent sleep disruptions, reduced sleep time, and increased wakefulness, are most prevalent among older adults and people with pre-existing sleep issues. Poor sleep increases the risk of obesity, diabetes, cardiovascular disease, depression, anxiety, and premature death. It can also contribute to traffic accidents and decreased job performance and productivity.[9] Few studies address cumulative exposures between heat and other environmental hazards, despite widespread interest in this topic within our region. One study found that indoor air pollution (PM 2.5 and NO2) amplifies heat health effects and associated symptoms among people with Chronic Obstructive Pulmonary Disease (COPD).[10] Another study on cumulative effects between heat and air pollution found an association with pregnancy-related complications but generalized across both indoor and outdoor exposures.

Efforts to mitigate indoor heat exposures have indirect health impacts. High energy bills resulting from increased AC usage put households at risk for high energy cost burdens[11], which can lead to utility arrearages and shutoffs for non-payment of utility bills. Nearly one in five households reduce spending on food, medicine, and other necessities to pay an energy bill. Even the threat of shutoffs can have long-term mental health impacts stemming from financial and environmental stress. Low-income, Black, and Latino households, households with children,

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[6] Baniassadi, A. and Sailor, D.J. (2018). Synergies and trade-offs between energy efficiency and resiliency to extreme heat – a case study. Building and Environment. 132: 263-272

[7] Kenny, G.P., Flouris, A.D., Yagouti, A., Notley, S.R. (2019) Towards establishing evidence-based guidelines on maximum indoor temperatures during hot weather in temperate continental climates. Taylor & Francis Group. 6, 11-36.

[8] Zhong, Q., Lu, C., Zhang, W., Zheng, Z., Deng, Q. (2018). Preterm birth and ambient temperature: Strong association during night-time and warm seasons. Journal of Thermal Biology. 78:381-390.

[9] Lee, W.V. and Shaman, J. (2018). Heat-coping strategies and bedroom thermal satisfaction in New York City. Sci Total Environ. 574, 1217-1231

[10] McCormack et al. (2016). Respiratory Effects of Indoor Heat and the Interaction with Air Pollution in Chronic Obstructive Pulmonary Disease. American Thoracic Society. 13,12. 2125-2131

[11] Energy burden is defined as the percentage of gross household income spent on energy costs. Households that allocate more than 10% of their gross income for energy expenses are considered energy cost burdened.

renters, and people living in poorly insulated homes are most likely to receive shutoff notices and service interruptions. Energy burden related stress can also affect the behavior, mental health, and academic performance of children.[12] Utility shutoffs or power outages (e.g., from excessive demand on utility grid) during a heat wave can also result in a loss of air conditioning (AC), refrigeration for medications, and electricity for medical devices, jeopardizing the health of the most medically vulnerable.

Risk Factors for Home Heat Exposure

Poor Access to Indoor Cooling

Increased prevalence of AC is strongly associated with reduced risk of heat-related illness and deaths, but access barriers undermine the effectiveness of this intervention. Studies have observed long-term declines in heat-mortality risk in countries and cities where the prevalence of AC has increased, including one study that tracked heat deaths across Canada, Japan, Spain, and the US between 1972 and 2009.[13] Conversely, several US studies and municipal surveillance programs have found significant associations between heat deaths and homes with no working AC. Even in US cities where AC prevalence is high, a large proportion of heat deaths occur indoors due to a variety of factors, including non-functioning AC units and rationing of AC to maintain costs. MAPC heat health project engagement has highlighted additional barriers to indoor cooling, including lease restrictions on window AC units, storage issues in overcrowded homes, and inability to install a window unit due to a disability. These access barriers contribute to heat-related health inequities. Residents in higher poverty neighborhoods are less likely to have AC and one study of four US cities found that disproportionately high heat deaths among Black residents can at least be partly attributed to lower prevalence of AC.

Some researchers warned that overreliance on AC is potentially maladaptive, even though large-scale surveys have found that people consider other heat coping strategies less effective and preferable.[14] Despite AC units becoming more efficient over time, the intervention is financially burdensome, further exacerbates climate change, and strains our electric grid. Its use may increase vulnerability during a power outage, if individuals that are dependent on AC have not been able to acclimate to heat or do not know how to deploy other heat coping measures.[15]

[12] Jessel, S., Sawyer, S., Henandez, D. (2019). Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature. Frontiers in Public Health. 7, 357

[13] Ito, K., Lane, K., Olson, C. (2018). Equitable Access to Air Conditioning: A City Health Department's Perspective on Preventing Health-related Deaths. Epidemiology. 29, 6.

[14] Williams, A.A., Spengler, J.D., Catalano, P., Allen, J.G., Cedeno-Laurent, J.G. (2019). Building Vulnerability in a Changing Climate: Indoor Temperature Exposures and Health Outcomes in Older Adults Living in Public Housing during an Extreme Heat Event in Cambridge, MA. International Journal of Environmental Research and Public Health. 16, 2373

[15] Gronlund, C. (2014). Racial and socioeconomic disparities in heat-related health effects and their mechanisms: a review. Curr Epidemiol Rep. 1, 3: 165-173.

High Energy Cost Burdens

Many households ration indoor cooling and maintain their homes at unsafe temperatures to compensate for high energy costs.[16] High energy burdens disproportionately affect BIPOC, low-income, and older adult households, as well as families that live in low-income multifamily housing, manufactured housing, and older buildings. The median energy burden of Black households is 43% higher than that of White, non-Hispanic households.[17]

A recent study reported that low-income and BIPOC households use more electricity per square foot in their homes than White and more affluent households, especially during the winter and summer heating and cooling seasons. This study was preceded by another that found a strong association between overall energy consumption and household size, wealth, and White population.[18] These findings suggest that low-income and BIPOC households live in less energy efficient housing, which requires more energy per square foot of living space to maintain safe or comfortable indoor temperatures, and that more affluent households consume more energy despite higher efficiencies. White and more affluent households are more likely to participate in energy efficiency rebate programs, which are better designed to meet the needs of single-family homeowners who can afford the upfront costs. Low-income renters have limited ability to persuade landlords to implement energy efficiency improvements, and both low-income renters and homeowners have limited financial means to make the repairs themselves.

Low-income households have few options to address cooling related energy cost burdens. The federally funded, but state administered Low-Income Energy Assistance Program (LIHEAP), provides eligible households with help paying a portion of winter heating bills. In many other states, primarily in warmer climates, LIHEAP is used to support households with both heating and cooling. Even if Massachusetts were to convert its LIHEAP program to address cooling-related energy costs, the scale of arrangements in the state would have ballooned over the course of the pandemic. The total amount of residential utility debt owed increased by 80% from $194 million to $351 million over a one-year period ending in November 2020 (NCLC, 2021).

Occupant Behavior

A large survey among residents of four North American cities found that only about half of respondents adopted heat coping strategies during heat events, even though knowledge of heat warnings was nearly universal.[19] There are several reasons people might not change their

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[16] Lee, W.V. and Shaman, J. (2018). Heat-coping strategies and bedroom thermal satisfaction in New York City. Sci Total Environ. 574, 1217-1231

[17] Drehobl, A., Ross, L., Ayala, R. (2020). How High Are Household Energy Burdens? An Assessment of Household and Metropolitan Energy Burden Across the United States. American Council for an Energy Efficient Economy

[18] Antonopoulos, C., Trusty, A., Shandas, V. (2019). The role of building characteristics, demographics, and urban heat islands in shaping residential energy use. City and Environment Interactions. 3, 100021

[19] Sheridan, S. (2007). A survey of public perception to and response to heat warnings across four North American cities: an evaluation of municipal effectiveness. International Journal of Biometerology. 51, 1: 3-15.

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behavior in response to heat, including lack of perceived risk or awareness of adaptation measures and physical or social limitations. Primarily older adults forego AC for reasons such as "disliking AC" or "not feeling hot".[20] Another study of older adult public housing residents found no change in hydration behavior during hot days, even in the absence of AC. Older age compromises people's ability to sense elevated body temperature and thirst, which can increase heat stress risk among older adults who are less likely to adopt heat coping strategies. People may also be reluctant to open windows because of increased exposure to noise and air pollution, especially in urban, high traffic areas. In neighborhoods that are perceived to be unsafe, people may be unwilling to open windows or travel to a cooler location due to fear of crime. Lack of affordable, reliable transportation also limits access to cool spaces outside the home. During the 1995 Chicago heat wave, people who did not leave their homes at least once a day, did not have access to transportation, or restricted ventilation in their homes by not opening windows had higher mortality.

Lack of Enforceable Indoor Temperature Standards

Massachusetts requires residential property owners to provide heat and to maintain both minimum and maximum temperatures during the residential heating season, which runs from September 15 to June 15. In contrast, the state does not require property owners to provide air conditioning, cool a home, or to maintain safe temperatures during warmer weather. While heating requirements are widespread across the country, few states[21] and cities require landlords to provide indoor cooling or to maintain the residential unit within maximum temperatures.

As temperature continues to rise across the country, it will become more difficult for residential property owners to ensure a safe living environment without also maintaining acceptable indoor summer temperatures. The difficulty in establishing an evidence-based safe maximum indoor temperature is that multiple factors affect people's thermal comfort threshold, including age, sex, pre-existing health status, level of acclimatization, as well as environmental conditions, such as humidity and level of ventilation. There is no comprehensive, reliable list of maximum residential temperature requirements across the country, but reported maximums vary across city and even type of cooling equipment provided. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) develops standards for professionals engaged in the maintenance of indoor environments. ASHRAE's standards recommend an indoor summer thermal comfort range of 23-28° Celsius (73-82° F), assuming occupants are dressed in clothing typically worn when the outdoor environment is warm. This range is considered to meet the needs of at least 80% of individuals. However, they may not reflect the temperatures at which

[20] Ito, K., Lane, K., Olson, C. (2018). Equitable Access to Air Conditioning: A City Health Department's Perspective on Preventing Health-related Deaths. Epidemiology. 29, 6.

[21] Most often, states require that an air conditioning unit be maintained if one was already provided at the start of the lease.

more vulnerable groups experience health impacts from heat such as children, older adults, and individuals with chronic health conditions.

Building Characteristics

Studies consistently supported the idea that specific building properties influence building heat gain and retention. However, most of these studies were conducted outside of the country, and those within the US are mostly limited to cities in the Southwest and New York City. The findings may not be locally appropriate given differences in building materials, housing types, and residential land use patterns between the study homes and homes within our region.

Characteristics relevant to building overheating included the thermal capacity and conductivity of construction materials, ventilation, location and number of windows, floor level, surrounding landscaping, and building size, orientation, and age.[22] Building type, such as single- or multi-family, was found to be less predictive of building overheating than other factors, such as building orientation and surrounding landscaping. Researchers in one study found greater variation within the same types of building than among different types. The most frequently listed heat-promoting building features included upper stories, a south facing orientation, and lack of surrounding greenery. In contrast, night-time ventilation, shading of the building envelope (both vegetated and structural), roofing insulation and light-colored coating were found to promote passive cooling.[23]

Findings were mostly mixed on building age and insulation, which has implications for residential energy efficiency. Many governments have established new efficiency standards and programs, emphasizing building insulation and airtightness to reduce energy consumption primarily during the winter heating season. Several studies found that these efficiency measures may inadvertently increase indoor heat exposure by diminishing nocturnal heat loss, especially if inadequate night-time ventilation is provided.[24] Many of the hottest buildings were older, but in some cases newer, more airtight buildings were found to be hotter than the older homes. The effect of energy efficiency measures, specifically insulation, on building overheating depends on climate and insulation characteristics. Energy efficiency appears to have an overall positive effect on indoor thermal conditions in warmer climates, while contributing to overheating in heating-dominated climates. Also, rooftop insulation was found to be consistently beneficial

[22] Mavrogianni, A., Wilkinson, P., Davies, M., Biddulph, P., Oikonomou, E. (2012). Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings. Building and Environment. 55: 117-130.
[23] Flores-Larsen, S. and Filippin, C. (2021). Energy efficiency, thermal resilience, and health during extreme heat events in low-income housing in Argentina. Energy and Buildings. 231, 110576.
[24] Baniassadi, A. and Sailor, D.J. (2018). Synergies and trade-offs between energy efficiency and resiliency to extreme heat – a case study. Building and Environment. 132: 263-272

whereas internal wall insulation was more likely to contribute to overheating.[25] More research is needed to understand specifically how energy efficiency measures, alongside other building characteristics, influence both energy consumption and heat resilience in our local context.

Location

Higher poverty neighborhoods and neighborhoods with more residents of color can be several degrees warmer than wealthier, whiter neighborhoods in the same city. Historic disinvestment in BIPOC communities has resulted in these neighborhoods having fewer green spaces and trees to shade homes and sidewalks and a higher proportion of impervious surfaces, contributing to the heat island effect. One study found an independent association between metropolitan area residential segregation and UHI neighborhood characteristics, suggesting that racially disparate exposure to UHI is worse in more segregated metropolitan areas. The same study also found an association between urban density and population size, which is consistent with the idea that segregation tends to concentrate BIPOC groups into densely populated neighborhoods, especially in larger cities.

Without more data on the relationship between indoor and outdoor temperatures, it is difficult to estimate the degree to which UHI increases risk for indoor heat health impacts. As the preceding sections suggest, multiple factors mediate exposure risk independent of a home's location. However, the higher concentration of less energy efficient housing coupled with less overall energy consumption and high rates of energy insecurity in these neighborhoods, suggests that these residents may experience greater exposure to high temperatures.[26]

Heat Risks Among Populations Experiencing Homelessness

Outreach to people experiencing homelessness is often a component of heat emergency response systems, yet there is little research on the specific risks to this population. People experiencing homelessness are amongst the most vulnerable groups, because they are also more likely to experience poorly controlled chronic health conditions, mental illness, social isolation, and interruptions to healthcare and social services. Most people experiencing homelessness live in urban or suburban areas where they are at a greater risk of exposure to extreme heat due to the urban heat island effect.[27] Conversations with homeless service providers in the region during summer 2020 surfaced specific heat coping challenges for unsheltered populations, including poor access to shade and water for drinking and bathing.

[25] Mavrogianni, A., Wilkinson, P., Davies, M., Biddulph, P., Oikonomou, E. (2012). Building characteristics as determinants of propensity to high indoor summer temperatures in London dwellings. Building and Environment. 55: 117-130.
[26] Antonopoulos, C., Trusty, A., Shandas, V. (2019). The role of building characteristics, demographics, and urban heat islands in shaping residential energy use. City and Environment Interactions. 3, 100021
[27] Ramin, B., and Svodoba, T. (2009). Health of the Homeless and Climate Change. Journal of Urban Health. 86, 4.

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Research Gaps

- Local, observational studies on the relationship between outdoor and indoor heat that can help researchers and local decision-makers better understand risk factors for residential overheating, including building characteristics, barriers related to indoor cooling, and opportunities to promote preventative measures among building occupants and owners.
- Locally appropriate thermal comfort thresholds for residential environments, especially among vulnerable groups.
- Local data on utility and debt burdens, energy assistance and efficiency program participation, disaggregated by race/ethnicity, household income, tenancy, and housing type.
- Evidence-based and methods for establishing, enforcing, and facilitating compliance with maximum temperature requirements, including ways to simultaneously achieve heat resilient and energy efficient housing.

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