Climate Change, Aging, and Well-being: How Residential Setting Matters.

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How Residential Setting Matters

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Trained in planning and architecture, Ann Forsyth works mainly on the social aspects of physical planning and urban development. The big issue behind her research and practice is how to make more sustainable and healthy cities. Forsyth's current research focuses on developing healthier places in a suburbanizing world, with overlapping emphases on aging and planned communities. She is the Ruth and Frank Stanton Professor of Urban Planning at Harvard University.

Abstract

How do older people's living environments influence their vulnerabilities to climate change? Much has been written about the physiological consequences of climate change for older individuals, particularly the dangers of increased incidence of severe heat. Less is known about how older people's residential settings moderate their exposure to climate stressors, their particular sensitivities to the effects of climate change, or their capacities to respond to extreme events or adapt to long-term environmental changes. Drawing on literature in English, with a focus on work relevant to the United States, we examine how the housing, neighborhood, and the urban or rural contexts in which older people live shape their experiences of climate change, moderating their exposure to risks related to climate change, sensitivity to those events and trends, and their capacities to adapt and recover. Older people face multiple life changes, making prioritizing climate readiness more challenging. They are also diverse, with different vulnerabilities and perceptions of risks and the ability to manage them. This paper lays out an agenda where additional research can inform policy and planning efforts aimed at reducing older individuals' risk and building capacity to adapt to climate change. The agenda includes understanding specific vulnerabilities and how older people and their housing providers are already responding.

Key Words

Climate change, planning, housing, seniors, older adults, well-being

Introduction: Older People and Climate Change's Effects

This paper addresses the intersection of two significant current challenges: the effects from global climate change and population aging. It examines a relatively understudied but central issue in understanding and addressing older adults' health risks from climate-change related events and trends; namely, how the settings in which older people live are moderating influences on their climate risks. It is well documented that climate change threats vary regionally in the United States and elsewhere, but the interaction of regional risks and residential setting is less understood. This relationship is a complex one, as threats from climate change are diverse and evolve over time, while older people are heterogeneous and face differing levels of vulnerabilities to those threats depending on a host of personal and social characteristics. In addition, older adults are themselves changing as they age, which may alter their personal vulnerabilities to climate threats.

The paper uses a narrative review to set out a research, policy, and planning agenda about how threats to older adults' health posed by climate change are affected by their residential setting, which includes the urban or rural character of the places in which they live, the neighborhood, and the home. We address one key question: How might residential location and character aggravate or ameliorate the effects of climate change on older adults' wellbeing? By teasing out the intersections between the literatures on aging, climate change, and older adults' housing situations, we propose that the residential setting is an important moderator of the effects of climate change on older people's health outcomes, affecting their exposures to climate-change related stressors, their sensitivity to those stressors, and their capacity to adapt in the wake of extreme events and evolving environmental conditions. Most work to date has been done on

other scales and dimensions such as the person or family, or on wider policy. The residential setting, particularly as it relates to vulnerable populations, is an area where future research could be fruitful and important.

While we focus on issues relevant to the United States, we draw on a larger international literature where it is relevant to the U.S. context, particularly research conducted in places with aging populations that are facing increased climate risks. The goal of the paper is to increase understanding about how urban/rural character, neighborhood, and housing matter to older adults' climate risks in order to inform the day-to-day practice of those involved in planning and housing at the municipal, metropolitan, and state levels.

In the remainder of this introduction, we summarize literature describing older adults' vulnerabilities to climate change threats given their exposure to specific stressors (such as extreme heat or severe storms), their sensitivity to those stressors, and their capacity to adapt to them. As we explain, people experience the effects of climate change in the specific place where they live, and this further shapes the risks older adults face, their reactions to events and trends, and their capacity to respond. After describing the methods in this review, we then examine research to date on the intersection of residential settings, aging, and climate risks.

In the conclusion, we point to areas where much more research is needed, particularly regarding older people's specific vulnerabilities and risks as they are moderated by residential setting; older people's responses to those risks; and how the policy and planning fields might more effectively communicate risks to older adults and center their vulnerabilities and needs in climate

action planning. A deeper understanding of these topics would strengthen policy responses to climate change and better target resources where they are most needed.

Framing Health Risks from Climate Change

In a helpful formulation, *vulnerability* to climate change is shaped by *exposure* to climate-related stressors, the *sensitivity* of a group or individual to those particular stressors, and people's capacity to *adapt* and respond (Balbus et al., 2016; McDermott-Levy Ruth et al., 2019). Balbus et al. (2016), drawing on (Gallopin, 2006), have defined vulnerability as a "predisposition to be adversely affected," exposure as contact between a person and stressors, sensitivity as the "degree to which people or communities are affected," and adaptive capacity as the ability to respond to and take advantage of changes. Older people, in general and as specific subgroups, face important challenges in each of these categories.

Exposure to certain risks varies by location, with some regions becoming increasingly prone to hotter temperatures and more frequent extreme heat events, while other places face greater incidence of severe storms or flooding. Stressors such as heat, insect- and water-borne illness, and lack of access to safe food and water are also anticipated to become more frequent as the climate changes, increasing chances of exposure to health-threatening incidents (Costello et al., 2009; Crimmins et al., 2016; Gabbe & Pierce, 2020). Together these risks threaten the health of great numbers of older adults: one estimate has suggested that more than half of the US population of older adults live in areas with high risk of extreme heat, forest fire, hurricanes, and coastal flooding (McDermott-Levy et al. 2019). Some areas that are attractive to those who move

in later years—such as coastal or warmer locations—may be particularly risky (Bukvic et al., 2018). Of course, subareas within regions may themselves present different risks of exposure: for example, heat island effects may create hotter temperatures in certain city neighborhoods than in rural surroundings or even adjacent neighborhoods with more tree cover.

Older adults' *sensitivity* to environmental stressors can be exacerbated by certain health conditions, social isolation, and even medications (Balbus et al., 2016; McDermott-Levy Ruth et al., 2019). Higher rates of chronic conditions and disabilities make older adults more susceptible to heat-related disease, insect-borne diseases, illness related to worsening air quality, and lack of access to safe food and water (Filiberto et al., 2009; McDermott-Levy Ruth et al., 2019), as summarized in **Table 1**. While that table focuses on physical and mental health, the range of potential effects would be wider if we examined the broader concept of wellbeing, potentially including additional financial impacts such as from higher costs of managing thermal comfort, or loss of income if someone is displaced (Haq et al., 2008; Porter et al., 2014).

INSERT TABLE 1 HERE

Sensitivity to climate threats is shaped by personal factors and social context, including demographic characteristics, economic circumstances, access to healthcare, social networks, personal health, and culture and beliefs. For example, a higher income may allow an older individual to use air conditioning during a heat wave, helping to reduce the risks of heat-related illness, while an older adult with cardiovascular disease and unable to afford air conditioning may be particularly vulnerable during the same event (Kenny et al., 2010). Research has also

explored the relationship between older adults living alone and susceptibility during major heat waves (OECD, 2015). Patterns can be complex; for example one study found that those with higher wealth living in physically vulnerable barrier islands had fewer social vulnerabilities than those living inland, where lack of wealth and social capital made people sensitive to hurricane risks (Wang & Yarnal, 2012).

Of course, climate threats themselves are shaping the social and economic contexts in which older people live. For example, unemployment, depopulation, rising insurance premiums, and abrupt home value depreciation following a major event can all contribute to individuals' sensitivities to future stressors.

Finally, *adaptive capacity* is also critical in shaping an individual or group's risk from climate change. Aside from higher-level efforts at mitigation—reducing the extent of climate change—personal and policy responses to climate change can alter an older person's risk profile and overall wellbeing (Leyva et al., 2017). Individual behaviors to help people cope or adapt include what can be seen as straightforward activities like moving to the basement or taking cool showers during extreme heat, or changing clothes or spending the day at a community center to keep warm when temperatures are cold (Kenny et al., 2010; Porter et al., 2014). Higher-level policy interventions, such as providing cooling or warming centers, also shape older people's adaptive capacity.

Individuals can also adapt to climate threats by permanently relocating. However, research on climate and relocation by older adults has focused most on moves made directly in response to a

disaster or to government buyout programs rather than how climate risks might be weighed in any moving decision. This research has found that relocation decisions are linked closely with personal perceptions of risk, community ties, place attachment, and personal control and self-efficacy (Cong et al., 2018; de Vries & Fraser, 2012; Seebauer & Winkler, 2020). In a review of literature on mobility in response to climate change, Otto et al. (2017) found that older people appeared less likely to relocate than younger households in response to both extreme events and slower changes, potentially as the result of limited physical abilities or ties to home and community. In general, older adults' relocation decisions are complex, driven by a variety of factors including attachment to home, desire for independence and control, and avoiding loneliness (Löfqvist et al., 2013), and as older literature notes, by a preference for certain amenities; housing that is more accessible, easier to care for, and/or more affordable; or proximity to family and friends to give or receive support (Litwak & Longino, 1987; Wiseman, 1980). Others have noted that federal flood insurance and wildfire policies may distort people's decisions to locate in or take protective measures against flood or fire threats (Anderson et al., 2018). Overall, however, little is known about the extent to which older adults factor climate risks into residential moves.

Older people in general may have less capacity to respond to climate stressors than younger people. For example, reduced mobility or hearing loss may make evacuation more difficult for older adults (Carter et al., 2016; McDermott-Levy Ruth et al., 2019; Oriol, 1999), though older people may also have resources and life experiences that serve them in recovering from a climate-related disaster (Leyva et al., 2017). A study of those 55-64, 65-74, and 75+ after Hurricane Sandy (N=1,000) showed that the oldest group was as likely as younger-old groups to

say they had recovered from the storm (Merdjanoff et al., 2019). A World Health Organization report noted that older adults can be active participants in a community's recovery after an extreme event, providing skills, resources, or emotional support (World Health Organization, 2008).

Within older populations, adaptive capacity is also shaped by financial resources and health, as well as social circumstances and networks. Al-Rousan et al. (2014), using data from the US Health and Retirement Study, found that those who were older, with physical disabilities, less education, and lower incomes had the worst overall preparedness for natural disasters. Of course, not all people agree that there is a climate problem, and even those who do may underestimate their own vulnerabilities and therefore fail to take preventative action to mitigate their risk (Ashida, Sato et al., 2016; Bichard & Kazmierczak, 2012; Thistlethwaite et al., 2018; Wolf et al., 2010). Social networks can help reinforce these perceptions.

Individuals' adaptive capacities are also affected by place-specific policy responses to climate risks (Balbus et al., 2016; McDermott-Levy Ruth et al., 2019). These responses vary considerably by location (Bierbaum et al., 2013; Shi et al., 2015) and the extent to which they take into account older adults' particular sensitivities. Limited but important research has touched on the need to include older adults in planning for severe events, ways to help older adults become more resilient to climate risk, and the needs of older adults in evacuation and recovery (Bernard & McGeehin, 2004; Hernández et al., 2018; McGuire et al., 2007; Rhoades et al., 2019).

Exposure, sensitivity, and adaptive capacity relate to the locations where older people live, which we term *residential setting* in this paper. While climate and extreme weather risks vary by region in the United States(Turner et al., 2003), this paper focuses on three lower levels of settings: location on the urban-rural spectrum (e.g. whether one lives in a core city, suburb, town, or rural area), the neighborhood context, and the home. These nested dimensions of where people live shape people's risks of adverse outcomes from climate change, so that residential setting acts as a moderating influence (or "moderator") that can exacerbate or reduce exposure, sensitivity, and adaptive capacity. Urban/rural setting, neighborhood, and home are also important because they are the subject of intervention by housing developers, local governments, and state agencies. Finally, because residential setting is closely tied with socioeconomic circumstances, individuals' choices about where they live—and whether they can reduce exposure or have adaptive capacity—are often limited, which raises important equity considerations. Altogether, residential setting provides a complex landscape in which climate change threats are experienced and managed.

Figure 1 describes how residential settings can influence the extent to which people are exposed to climate stressors, shape their sensitivity to those stressors, and support or impede adaptation and response, ultimately affecting older adult's health, the outcome of interest in this paper. The figure illustrates our proposition that the specific climate change risks one faces are moderated by the nature of one's living environment—from the level of the house to its location within the region. Much of the current literature leaves implicit how exposures, sensitivity, and adaptation affect health, and this figure makes one important pathway—the residential setting—explicit.

First, residential setting shapes exposure (pathway A). While risks vary regionally, with places prone to broad risks from wildfire, severe storms, extreme heat, etc., the severity of a particular risk to an individual can depend on one's location within a region or even a neighborhood. For example, a coastal area is likely more prone to flooding than an inland neighborhood, while urban neighborhoods with few green spaces may experience higher temperatures during an episode of extreme heat than nearby neighborhoods with parks and tree cover. The home can also influence exposure. For example, a home built on stilts in a flood prone location, or one retrofitted with fire-resistant siding and roofing in areas with high wildfire risk, may reduce the severity of exposure to occupants.

Residential setting also moderates sensitivities (pathway B). For example, a low-income renter household may have little control over temperature or air quality in their building, creating greater sensitivity to or degree of effect of extreme heat or cold, mold after floods, or even wildfire smoke that comes into the home via poorly sealed doors and windows.

Finally, individuals' abilities to respond or adapt to climate threats are affected by residential setting as well. Disaster preparedness, for example, varies by state and community, and even by neighborhood and residential building types (pathway C). For example, older adults' abilities to cope with the immediate aftermath of a severe storm may be hampered if they live in high-rise buildings that have lost electrical power—and therefore elevator service, as occurred after Superstorm Sandy.

Exposure, sensitivity, and adaptive capacity—as moderated by residential setting—result in vulnerability and finally health outcomes (pathways at the bottom half of the figure). INSERT FIGURE 1 HERE

As described above, residential setting has a direct moderating effect on health outcomes in the immediate time of a storm, flood, or heat wave, but because residential setting can affect mental and physical health in general, it can also predispose people to certain sensitivities or shape adaptive capacity over time. For example, substandard housing can contribute to poor health directly (not shown on the figure), which in turn increases sensitivities to climate stressors.

These relationships between setting and vulnerability are complex and multidirectional. An older adult in an economically distressed rural community may have poorer health given a host of factors not related to climate change (e.g. poor access to medical care, lack of health insurance, etc.), but this poorer health may increase sensitivities to climate stressors. Meanwhile, a lack of resources in the area may limit funds to repair housing after a climate event, further contributing to poor health. The interactions between climate change, residential setting, and older people's health are also occurring in a wider political, social, and economic context (see upper right of **Figure 1**).

Much of the literature on climate change does not focus on older people as a separate group and, where it does, it seldom explicitly examines the vulnerabilities associated with their residential settings. But these urban-rural, neighborhood, and housing settings shape exposure, sensitivity, and adaptive capacity and are potentially important for understanding and managing a wider range of climate threats. By reviewing the literature that does examine these connections, we

chart out what is known about this wider range of areas of concern and where more work is needed to inform effective policy and planning.

Materials and Methods

Our review focused mainly on literature relevant to the U.S., and included research conducted in the U.S. as well as that in other places experiencing both climate change and population aging that is pertinent to the U.S. context.

This is a narrative review, not intended to be comprehensive but rather to explore the variety of issues and areas where future research would be helpful. We chose a narrative review because the question of how residential setting moderates climate-change risks, sensitivities, and adaptation among older adults is itself under-explored (a review of research focused explicitly on this topic would be quite short) and because answering this question involves many overlapping literatures. These include reviews on the effects of climate change on older people's wellbeing, some of which have explored how climate change influences health (looking largely at the individual level and at broader policies not specifically related to locations, as cited in Table 1). Other research has explored the path from climate change, through individual and social factors, to wellbeing. Through this literature, we inferred likely patterns of exposure, sensitivity, and adaptive capacity among older adults in particular settings. A second literature, focused on setting and climate, has typically looked at the general population and not older adults specifically; we drew from this to speculate about likely patterns for older people. Finally, another body of work has examined issues related to aging and residential setting but not climate risk. By drawing from these literatures, we set out issues at the intersection of aging, residential

setting, and climate change, but also show how future research that does focus specifically on older people in particular settings is likely to uncover important patterns.

Not all the literature we identified came from academic research; we included some gray literature as well. However, even the academic research covered a range of topics and involved different methods. With this broad, emergent literature, we saw our aim as providing a big picture look at the role of the residential setting in older adults' climate risk. We organize the results by scale of setting (rural/urban dimension, neighborhood, and house or apartment) and then discuss key themes emerging from this analysis.

While this is not a systematic review or another type that addresses study quality, the issue of quality is of course important. Many of the studies with well-designed empirical and analytical strategies were narrowly focused on a topic such as the effects of a specific event on public housing. These single studies on a narrow topic provide some guidance about the general issue of hazards and housing, but a very small slice of that issue. While there may be high quality work in existence it provides a patchwork of small snapshots of parts of the larger problem, leaving many gaps. Other work may be of high quality but about the general population, leaving room for questioning how it might be applied to older people. Overall, this is still an emerging area.

This strategy for mapping out how climate change affects older people's health as moderated by their residential setting brings some limitations. The experience of older people in residential settings is affected by policies, programs, and other actions conducted by various levels of government—national, state, and local; these are key factors but here the focus is on the

residential setting itself. Mitigating climate change by reducing fossil fuel use and other means is also very important, and older people have a part to play. However, this paper emphasizes climate change effects and the potential for adaptation. Finally, housing markets are of course important mechanisms for allocating housing to older people. This paper addresses some of the disparities of such markets but more centrally addresses the physical locations where older people reside. Finally, we examined older adults residing in the community and not in group quarters such as nursing homes or hospices. Though older people living in group quarters are among the most vulnerable to climate-related stressors given frailty, poor health, and reliance on others for care and transportation, our focus here is on the large majority of older adults living in their own households or in those of family who may be more able to take personal action to address climate risks.

Results

Three main scales of concern frame the intersection between the residential settings of older people and their vulnerability to climate change risks—their location along the urban-rural spectrum, their neighborhood, and their home. These setting-related climate change risks are layered on top of an already complex relationship between the wellbeing of older adults and where they live. In addressing how the location and character of older adults' housing and neighborhoods might aggravate or ameliorate the effects of climate change on their wellbeing, we first discuss how factors related to levels of urban and rural settings can moderate climate change risks. We then turn to the neighborhood level, exploring the built environment, services, and other aspects of local life that affect older people, and finally address the home itself.

The Urban-Rural Spectrum

Across regions, different levels of urbanicity or rurality affect older adults' exposure to a range of climate-related stressors (for example, wildfires are more common in lower-density locations). Location on the urban-rural spectrum can shape sensitivities and adaptive capacity, through differential access to healthcare, supports and services, recreation and social engagement, and other services and amenities. There is no perfect location in terms of density or settlement size, or other factors that vary among rural and urban places such as the mix of services, social opportunities, and the economic base. However, different kinds of places present different problems and opportunities.

Rural and Lower-Density Areas

About 25 percent of older adults in the US live in rural settings (outside of metropolitan areas) (Nash et al. 2017). While definitions of *rural* vary, in this review we use it to mean places with low population densities that, in the US, are outside of metropolitan statistical areas or in the outer regions of metro areas.

Lower-density areas include parts of metropolitan areas often characterized by reliance on automobiles for transport. Many baby boomers live in lower density locations, and analysis of Census data has shown an increasing concentration of older adults in such locations, particularly the least dense third of metropolitan areas (Joint Center for Housing Studies, 2019). While many older people in suburban areas are comfortably well-off, many also moved to and stay in such

areas because they were less expensive than core cities. Yet even the comfortable face challenges if they become disabled or need supportive services to remain in their homes.

In rural areas some challenges for older people are related to the healthcare system. Rural areas have lower rates of health insurance, fewer medical providers, and limited transportation to access healthcare sites (Smith et al., 2008; UNECE, 2017). Rural areas with aging populations may also face the added challenge that healthcare workers are themselves retiring (Jensen et al., 2020). In general, provision of supportive services by home health aides, physical therapists, meal delivery programs, etc. can be difficult in low-density areas, given greater distances and a lack of transportation alternatives to the private car. Broadband access tends to be more limited than in urban areas (Perrin, 2019; Swenson & Ghertner, 2020).

In part of result of these factors, rural populations have higher rates of conditions and chronic diseases linked to obesity, physical inactivity, and food insecurity than suburban counterparts, including heart disease, cancer, diabetes, and depression (Nash et al. 2017, Durazo et a., 2011). Older adults dwelling in rural locations and small towns may also be more likely to be socially isolated (Kaye, 2017), and isolation may be exacerbated by lack of reliable broadband. Rural areas and their populations vary considerably, however, from areas with high poverty to amenity destinations (Jensen et al., 2020; Skoufalos et al., 2017; Smith et al., 2008), complicating understanding of these differences.

Given higher rates of health challenges, limited infrastructure and medical services, and greater distances to services, older adults in low-density and rural areas may have greater sensitivity to

climate-change related events than those in higher-density locations. They may also have less adaptive capacity. Social isolation, lack of resources, and lack of family support may impede personal preparation for severe events (Ashida, Sato et al., 2016). If evacuation is necessary in the face of a storm or wildfire, many older adults would need transportation and support, particularly those with serious health conditions, yet these services may not be available in isolated areas, and those with mobility or cognitive challenges may need specialized assistance (McDermott-Levy Ruth et al., 2019; Rosenkoetter et al., 2007; World Health Organization, 2008). Access to heated or cooled spaces—like shelters, libraries, and private shopping centers—may be more difficult in lower-density locations than urbanized areas. Research by (Fraser et al., 2017) in Los Angeles and Maricopa (AZ) counties found reduced access to cooling locations outside of urban areas, and that lack of transportation options in these areas further limited access to air conditioned locations. In the aftermath of an event, it may also take longer to reach people in need in low-density areas or to restore services and electrical power. In a study of Puerto Rico's recovery from Hurricane Maria, Román et al. found that 41 percent of rural communities experienced power outages exceeding 120 days, compared with 29 percent of cities (Román et al., 2019).

While housing is discussed in greater detail below, rural housing in the US does share some broad characteristics that may shape older adults' exposure and sensitivities to climate. Those in lower density areas tend to be responsible for more residential property, which can increase the physical demands associated with preparing for climate change effects, such as the need to clear brush away from homes in fire-prone areas. While people in rural areas may have access to the beneficial aspects of contact with nature, homes in rural areas are more likely to have quality

problems than those in urban settings, with housing on tribal lands particularly deficient. Rural housing is also more likely to be owner-occupied, which allows the owner control over repairs and climate resiliency upgrades, but these can be beyond the means and capacity of many rural residents, including older adults (Rural Housing Coalition, n.d.).

Higher Density and Core City Locations

In general, the denser and more central parts of urban areas may offer greater access to healthcare and proximity to certain services and amenities. Globally, the older population living in urban areas is increasing. While in the US there has been more growth in older populations in suburban and low-density locations, still the number of older people in central cities is on the rise (Joint Center for Housing Studies, 2019).

Living in such dense areas may not be a panacea for older people, however, particularly for low-income older people and those with disabilities. Highly urbanized locations have specific climate-related risks, including higher temperatures due to urban heat island effects, which can also create greater exposure to air pollution (Carnes et al., 2014; Depietri & McPhearson, 2018; Kovats & Hajat, 2008). Many older people live in cities increasingly prone to flooding (Bukvic et al., 2018), where severe storms bring particular risks. Storm surges leading to power outages can leave older adults and those with disabilities stranded in their apartments when elevators become inoperable. Hurricane Sandy resulted in 700 inoperable elevators in New York City Housing Authority apartments alone, and power to some high rises was not restored for weeks (Hernández et al., 2018; Manuel, 2013). Climate-related challenges are also particularly great for lower-income people (disproportionately people of color), who often reside in areas more likely

to flood and/or have poor drainage. As in rural areas, evacuation from rising waters is also a concern, and those reliant on public transportation may have limited options (Szewrański et al., 2018).

As in rural areas, the characteristics of housing also play a role in shaping exposure and sensitivities to climate change. As noted, high-rises may present particular challenges during periods of power outages. A higher share of rental housing means the responsibility for quality and climate preparedness falls more on landlords, and incentives for owners to address resilience of the building structure vary by rent level and may also bring the potential for climate gentrification, resulting in increased rents and displacement (Hijazi, 2020).

Urban-Rural: Conclusions

All types of environments have challenges, some related to the social determinants of health that shape people's health and therefore their sensitivities to climate change, and others to their exposure to specific risks and the resources available to help people recover from specific climate-change related events and to adapt to climate changes more generally. Within urban or rural communities, there is also great variation in exposure and resources, and the intersection of population and place plays an important role in individuals' risk profiles.

In general, however, lower-income older adults and older people of color in all locations are potentially more vulnerable due to systemic inequities that have led to poorer health and fewer resources. As Smith et al. (2008) have noted, health outcomes tend to be worse in areas with high poverty and low rates of education, whether urban or rural. Yet more could be known about how

geographic location and socio-economic characteristics intersect to produce specific climate-related risks for populations of older adults. While risks will change over time with climate change, some assessment would help target policies. We return to this issue in the discussion.

Neighborhoods

While climate change risks are often viewed regionally, they differ by the nature of places within regions and are also experienced in a more localized manner, at the scale of the neighborhood. Neighborhoods lack a consistent definition but here we refer to the areas around where older people live that they experience in their daily lives. Those with low incomes and wealth have fewer choices about where they live, and often find that lower cost housing is located in riskier areas with limited options for relocating out of harm's way if certain threats (e.g. sea level rise) become more salient (Crimmins et al., 2016). In their 2013 article, (Gamble et al., 2013)noted that high-risk areas had higher concentrations of lower income older people, and that low socioeconomic status could hinder access to resources post-disaster.

Neighborhood features have also been associated with poorer health outcomes among older adults, particularly for those living in economically disadvantaged places over long periods of time (PRB, 2017), which may increase sensitivities to climate-related events. However, again, this can be complex with some affluent older people living in scenic but physically vulnerable areas (Wang & Yarnal, 2012), and lower income people living in vulnerable locations with constrained public resources but near to familial support systems. Neighborhood density itself can present both advantages, such as easier access to resources, and disadvantages, such as

greater risk from damage to nearby structures (Irajifar et al., 2016). Infrastructure and social networks in these locations also can influence adaptive capacity.

Infrastructure and Services

The availability and resilience of neighborhood physical infrastructure, including that related to utilities and transportation, can affect older adults' exposure to climate risks (Gamble et al., 2013; Haq et al., 2008). Infrastructure directly related to climate change effects is important – levees, seawalls, bioswales, and green infrastructure can reduce risks to people and property in particular locations. However, infrastructure also supports older adults during and after extreme events. Electrical grid capacity and vulnerability can affect people in a number of ways: heavy demand for electricity during heat waves can lead to brownouts or blackouts—while the same can happen during periods of extreme cold in milder climates, as was the case in February, 2021 in Texas, when millions lost power (Busby et al., 2021). These situations can be particularly dangerous for those with health regimens that rely on electricity, such as those using oxygen concentrators. Meanwhile, transportation infrastructure is critical in times of evacuation or to access services to manage new risks, particularly for those who do not drive (Goins et al., 2005; Molinsky & Forsyth, 2018)or for those needing to travel shorter distances to reach cooling or warming shelters. Neighborhood services can protect or ameliorate some of the risks of climate stressors, reducing sensitivity and bolstering adaptive capacity. Neighborhood cooling centers, for example, can provide places to escape extreme heat for those who lack or cannot afford to run air conditioning (Fraser et al., 2017).

Another important consideration at the neighborhood level is coordinating infrastructure and services. It may not be enough to have services available during extreme weather if communication or transportation infrastructure does not make it possible for residents to access them. For example, in the 2021 Texas power outages, poor road conditions, including unplowed roads, made it difficult for older people to reach warming centers (Busby et al., 2021). Mass transit can be critical as well for the same purposes, but service availability, reliability, and resilience can vary at the neighborhood level. Communications infrastructure is also important: access to broadband can provide invaluable information about preparation and evacuation, but many low-income households and those living in low-income neighborhoods may lack service, due to availability or expense. Older adults may also lack experience using technology (Anderson & Perrin, 2017).

Individuals' risks are exacerbated or mitigated by the extent of their exposure to these stressors, which can vary even at the local level. For example, temperatures can vary within urban areas due to differences in impervious surfaces, wind patterns, and tree cover (Huang & Cadenasso, 2016). Previous studies have highlighted disparities in green infrastructure (e.g. parks, forests, trees) within cities that can affect temperature and other climate stressors (for example, McDonald et al., 2021; Rigolon, 2016). Green infrastructure may also help promote general health, including among older adults. (Dennis et al., 2020) analyzed spatial, demographic, and socio-economic data in the Manchester, England area to find that older people in lower-income areas may benefit especially from access and proximity to certain types of green infrastructure.

Accessibility of neighborhood environments also affects older people's opportunities to socialize (and avoid loneliness) and meet their daily needs, but also to create nearby social networks to enhance resilience (Cohen-Mansfield et al., 2016; Forsyth et al., 2019).

Social Networks and Neighborhoods

Local social networks can affect older adults' risks to mental and physical health during and after natural disasters and extreme weather. As noted by (Heid et al., 2017) "Neighborhood social capital can act as a resource, supporting the ability of people to cope with stressors as well as their mental and physical health declines" (p. 742). In contrast, breakdowns in social networks and support systems can have devastating effects, as discussed in Klinenberg's analysis of the 1995 Chicago heat wave in which over 700 people died, many alone and at home (Klinenberg, 2015).

Social networks may influence behaviors regarding preparing for extreme events, as well as decisions to evacuate in times of imminent danger. After an event, a loss of communication infrastructure may mean that one's local network of neighbors is particularly important for sharing information (Heid et al., 2017).

Social networks also contribute to personal resilience to natural disasters and other climate threats (McDermott-Levy Ruth et al., 2019; Walker & Burningham, 2011). In an analysis of panel data for over 2,200 older adults in New Jersey who had experienced Superstorm Sandy, Heid et al. (2017) found that post-traumatic stress disorder (PTSD) symptoms were less prevalent among older adults who perceived their neighborhoods as having greater social

cohesion and higher levels of trust. Social networks are not always positive, however. An interview-based study in the UK of 65 older people and 40 social contacts, most from the same city, found that strong bonding networks reinforced older people's sense that hot weather would not affect them (Wolf et al., 2010).

Neighborhoods: Conclusions

Exposure to climate stressors can vary by specific location, even at the neighborhood and sub-neighborhood levels. Through supportive infrastructure, services, and social networks, neighborhoods can buffer older adults against the effects of climate change, but the absence of these can exacerbate sensitivity to climate stressors and reduce older adults' capacity to recover from extreme events or adapt to new realities, such as warmer temperatures or more erratic weather. Yet while older people can be vulnerable to infrastructure weaknesses and failures, they may also have reserves of resilience that can help in neighborhood recovery.

Housing

Finally, the home also influences older adults' exposures and sensitivities to climate risks as well as their adaptive capacities. Important dimensions of the physical home include its location (discussed above) and its quality, including its ability to withstand particular climate stressors. The role of housing in climate risks to older adults is also manifested through household factors that tie directly to the physical home, including tenure (whether the home is owned or rented) and affordability.

The Physical Home

As described in greater detail below, the *physical structure* of the home plays a key role in safety from the elements, including in sheltering from heat, cold, and storms. Climate change will place new burdens on the physical home (Snow & Prasad, 2011), as shown in **Table 2**, including increased likelihood of damage from storms, floods, and fires, and strains on building components from heat, water, and wind. Indoor air quality may also worsen with greater moisture and mold and the presence of wildfire smoke (Boch et al., 2020; Gibney et al., 2018; Lewis et al., 2010; Snow & Prasad, 2011). Certain structure types may be more susceptible to certain climate stressors, such as mobile homes in areas that experience severe storms and high winds or housing in proximity to the oceanfront. Housing's quality and ability to withstand damage from extreme events or temperatures may affect the health of occupants of the home through increased risk of respiratory illness, heat-related illness, and other adverse outcomes and injury. As **Table 1** described earlier, older adults may be particularly susceptible to these given preexisting conditions and frailties.

INSERT TABLE 2 HERE

Since older adults in general spend most their time inside their homes, these issues may be particularly salient. Additionally, older adults tend to have resided in their homes longer and therefore have older homes (Joint Center for Housing Studies, 2014), which may mean they need maintenance and may lack modern climate-related features, like fire-resistant siding or other climate-responsive design. For example, a study of LEED building strategies that fostered climate resilience in Austin and Chicago found that LEED-certified buildings were less

concentrated in areas with vulnerable populations including those 65 and over (Houghton & Castillo-Salgado, 2020).

Of course, homes that are made resilient to the particular climate threats or that benefit from community-wide adaptations (e.g. defensive infrastructure) within a region and neighborhood can often help reduce occupants' exposure. Designs and materials that encourage cooling, for example, can help protect older adults vulnerable to heat-related illness, while roofs with higher wind resistance are important for those in hurricane-prone locations. Fire-resistant roofing and siding and certain landscaping practices can reduce the risk of wildfire damage to a home, as can moving mechanical systems out of the basement in flood-prone areas. Little is known about the share of older people's homes with these features.

Heating and Cooling

One's housing can protect against or exacerbate the effects of extreme heat through mechanisms such as insulation, thermal mass, ventilation, shading of the home, high ceilings, and having cooler rooms (e.g. those with air conditioning or fans, or basements) (Kovats & Hajat, 2008; Loughnan et al., 2015; Nunes, 2018; White-Newsome et al., 2011). In the U.S. there are disparities in home air conditioning by race (O'Neill, 2005) and age of home (with older homes less likely to have air conditioning) (Fraser et al., 2017). Furthermore, as the climate changes, older residential structures in traditionally milder climates that were designed to retain heat in cold months may pose difficulties as average temperatures increase (Williams et al., 2013). (Gronlund et al., 2016) found greater vulnerability to extreme heat among older adults living in homes built before 1940 and in cities with lower rates of residential air conditioning use.

Even the presence of an air conditioner may not be sufficient; broken units, loss of electricity, or cost can prohibit some from using them (Doremus et al., 2021; Iverson et al., 2020; Lundgren-Kownacki et al., 2018). An individual's possible responses often depend upon their resources, including their ability to afford higher utility costs. However, while in the U.S. social deprivation predicts heat stroke mortality, evidence from Europe is less clear (Kovats & Hajat, 2008).

Heating is also an issue, as climate change may bring more unexpected extreme cold events (McDermott-Levy Ruth et al., 2019). Again, loss of power may prevent people of any income from keeping warm, but lower income older adults are more likely to be energy insecure and therefore have difficulty paying for heating when it is available (Jessel et al., 2019).

Resistance to Flood, Wind, Fire, and Smoke

Millions of US homes are vulnerable to damage from flooding, high winds, and wildfires, putting residents at risk of displacement, injury, respiratory or vector-born illness or disease after a flood event, or respiratory illness from wildfire smoke infiltrating to the interior of the home. Housing design, building materials, landscaping, and siting on a parcel of land can affect risks from floods, storms, and wildfires, as noted earlier. Most older adults in the US do own their homes, putting many adaptive measures within their control; and further, most have lived in their homes for decades, suggesting their homes could particularly benefit from more recent building technologies for reducing climate risk (Joint Center for Housing Studies, 2014). However, relatively little is known about older adults' efforts to retrofit their homes, though lack of wealth, disposable income, awareness of climate risk, or information about retrofitting strategies (particularly for those lacking internet access or computer skills) may prevent older owners from

taking action (Bichard & Kazmierczak, 2012), and lack of physical strength or energy may prevent older adults from doing some tasks themselves (Brockie & Miller, 2017). Adaptation may bring challenges of its own. (Nelson et al., 2021), in a study of coastal Louisiana, reported examples where elevating homes above flood level made them harder to manage with age given added stairs.

Housing Quality

Housing quality is important for sheltering occupants of a home from the elements, and older adults are no exception. In general, poor quality housing, or housing that has not been maintained, may be less resilient to climate stressors (Boch et al., 2020; Gibney et al., 2018; Lewis et al., 2010; Snow & Prasad, 2011). In the US, 131,000 very low-income renter households (those earning below 80 percent of the area median income) aged 62 or over lived in severely inadequate housing in 2019 (defined as having at least one serious physical problem related to heating, plumbing, or electrical systems, or maintenance) (U.S. Department of Housing and Urban Development, 2021). Older adult owners often have deferred maintenance needs, spending less than younger households (Begley & Lambie-Hanson, 2015).

Homes that are not formally identified as inadequate may still present dangers to occupants given the particular combination of climate change risk and house type and materials. For example, people living in manufactured housing in areas with the potential for high wind events may be more vulnerable than neighbors in single-family homes (Sutley et al., 2020). Similarly, specific housing features can be problematic in certain environments. For example, the level of sealing of

the building environment can affect the infiltration of particulate matter from wild or bush fires (Kirk et al., 2018; Rajagopalan & Goodman, 2021).

The Physical House: Conclusions

The physical home influences exposure to risks, with different structure types more vulnerable to specific climate-related events. The home can also exacerbate sensitivities; homes prone to dampness or mold can worsen respiratory issues in the wake of a flood, for example. Finally, the physical home can help or hinder adaptive behaviors such as keeping cool in extreme heat.

The extent to which older people recognize limitations of their homes and retrofit them for the changing climate is less clear, as are the barriers to making changes and the incentives that might encourage them to address deficits. Something is known about resident behaviors for mitigating risks: for example, opening windows during wildfire smoke event will reduce the efficacy of systems designed to reduce outside air infiltration, while using blinds or fans during heat events can help reduce indoor temperatures (Lundgren Kownacki et al., 2019; White-Newsome et al., 2011), yet more involved behaviors (such as retrofitting the home or even relocating) have been less studied.

The physical attributes of temporary shelter for those displaced by climate-related events are also important. Temporary housing may be crowded, increasing the chance of infectious disease transmission; located in inaccessible structures that pose barriers for those with mobility difficulties; or may separate older adults from their support network (World Health Organization, 2008).

Other Housing Characteristics

In addition to the physical home, housing tenure and affordability shape older adults' exposure, sensitivities, and ability to adapt to climate change effects. While not the main focus of this paper they provide key context.

Tenure

Housing tenure regulates people's relationships to their homes. Older adults in the US have the highest homeownership rate of any age group at 78.5 percent of households age 65 and over in 2018 (Joint Center for Housing Studies, 2019). However, there are wide gaps in US homeownership rates by race and ethnicity—indeed, in 2018, the Black-white homeownership gap for older adults stood at 19.4 percentage points, a 30-year high (Joint Center for Housing Studies, 2019). Most owners live in single-family homes that require ongoing maintenance and investment to remain resilient to climate change, which can become difficult in older age and on fixed incomes. As noted earlier, older homeowners are also more likely to need to cope with climate stressors on their own rather than with the assistance of staff in a senior housing complex, for example (Harris, 2018).

Yet compared to renters, owners may have more opportunities to address physical deficiencies in their homes or take steps to make them better able to withstand climate change threats, from high winds to potential flooding. Owners tend to have higher incomes and much greater wealth than renters, in both housing equity and non-housing assets, and therefore have greater resources to expend on adaptive measures, healthy home modifications, and maintenance. There is little

literature, however, on the extent to which older homeowners make changes to their homes to address risks to their wellbeing, e.g. adding air conditioning or fire-resistant siding or roofing. There is some literature on efforts by owners of age-restricted housing to make buildings more energy efficient, which in some cases can improve indoor air temperature and comfort level for residents (e.g. Ahrentzen et al., 2015; Makantasi & Mavrogianni, 2016). For example, in their analysis of energy retrofits in an apartment complex inhabited by low-income older households, (Ahrentzen et al., 2015) found that energy efficiency improvements also resulted in better indoor thermal regulation and overall resident self-reported health.

Housing Affordability

Housing affordability affects the household budget, and therefore people's abilities to pay for maintenance and retrofits, as well as other health-related necessities like food and healthcare (Jessel et al., 2019; Joint Center for Housing Studies, 2019; Tonn & Eisenberg, 2007). Over 10 million older households in the US—fully one-third of all older households—pay more than 30 percent of their income for housing (Joint Center for Housing Studies, 2019). Low incomes and lack of sufficient supply of affordable housing can also push older people to live in substandard conditions detrimental to health (Bashir, 2002) making them more vulnerable to damage from wind, floods, or fire (Ross, 2013).

Of course, one's ability to comfortably afford housing does not remove climate risk. While public subsidies assist low-income households in affording housing, a recent study of 1.5 million federally-assisted housing units in the US found that 38 percent of older households (defined as

headed by someone aged 62 or over) living these units were at very high or relatively high risk of a natural hazard including those related to climate change (PAHRC & NLIHC, 2021).

Reflections and Implications: What Is Known about Older People, Residential Settings, and Climate Change

Certainly, much is known about the effects of climate change on older people, particularly based on their social and personal characteristics. However, as we have argued, residential settings also affect older people's exposure to climate change threats, sensitivity or degree to which they are affected, and their ability to adapt to those threats.

Exposures and Sensitivities

Depending on region and localized conditions, exposure threats may include extreme events such as severe storms, floods, and wildfires, as well as threats from changing weather patterns, such as hotter summers and more frequent droughts. The most studied area of risk for older adults appears to be vulnerability to extreme heat. A great deal is known, for example, about how older adults may be more vulnerable to extreme heat based on their underlying health, behaviors, and social networks, and research has focused on the specific risks for those living in older, unairconditioned homes (or who cannot afford to use air conditioning).

While setting has been explored to some extent in understanding older people's exposures and sensitivities, planners and policy makers still lack an overall sense of how many older adults are at risk from specific climate stressors depending on where they live. Regional risks are somewhat understood, but we lack a full picture of older households' climate risks based on

where they live on the urban-rural spectrum, the characteristics of their neighborhood, and their individual homes.

Different kinds of older people also face different challenges from the same climate changes. Older adults are a heterogeneous population that includes those in robust health and those that are frail, people who live with extended family and those who live alone, and those with extensive financial and social resources and those with few. As noted in **Figure 1**, social and individual factors play an important role in one's climate exposure and sensitivity. Those who are socially vulnerable face significant challenges in any location, but the specific ways older experience climate change are moderated by residential setting.

Adaptive Capacity

For older adults, time is a key challenge in that multiple, complex changes are happening at once and mostly in the direction of needing action. Climate risks are evolving; individuals themselves are aging (which can increase sensitivities to climate stressors); neighborhoods are changing, which may alter support networks or even affect exposure to specific climate threats; and homes may be deteriorating due to lack of maintenance (Mackenzie et al., 2015; Molinsky & Forsyth, 2018). These overlapping, pressing, and at times sudden, challenges make it particularly difficult for older adults to identify action steps to address potential future risks and problems. This is true at the societal level as well, where predicting climate-related hazards across geographies to older adults and their support systems is complex (Oven et al., 2012).

For older adults, navigating changes in life stage and health, and subsequent changes in housing and support needs, may mean climate change garners less of their attention. Drawing from

psychology, (Adger et al., 2009) have noted in their analysis of social limits to adaptation to climate change that people respond to "issues, risks or concerns they consider as immediately and personally relevant" (p. 347). Older adults may also consider climate change as having a longer time horizon and not likely to affect their health in their lifetimes (Akerlof et al., 2015).

It is also difficult for many people to consider longer term climate changes in making decisions about where they will live (Porter et al., 2014), but older people have additional challenges. Some may have lived in an area for a long time and don't want to leave and disrupt patterns of life, and options for where to move may be constrained by budget, the limited availability of accessible housing, or the need to near a support network. Others may move to seek certain amenities, such as warmer weather, yet the moves they do make may actually increase their risks. For example, moves to the Sunbelt may expose older adults to more days of extreme heat or increase the chance of severe storms. Others moving to less vulnerable areas may drive climate sprawl (new growth on the urban edge) or climate gentrification where those with resources move to areas with fewer risks, driving up prices (Forsyth & Peiser, 2021).

Actual control over one's immediate situation regarding climate change also varies. In preparing for extreme weather or higher temperatures, housing tenure matters, as owners, renters, and those living in another's household (such as that of a child) may have different levels of control over their immediate environment. Those with higher incomes and savings have more resources to take steps to prepare their homes or move to safer locations, though they may not do so. During extreme events, people needing assistance or medical equipment to evacuate must rely on others

for assistance, while healthier older adults may have more control over their personal safety (though certainly this means they can also act in ways that do not enhance their wellbeing).

Risk perception also varies among older adults. Many articles have explored how individuals understand the risks of climate change, or even if climate change is indeed occurring, with many examples of lack of knowledge or downplaying risk. For example, a survey of 2,300 Canadians living in designated flood risk areas found that only 6 percent thought they lived in such an area; flood concern was also low (Thistlethwaite et al., 2018). Differences in risk perception vary by exposure to severe events or even the temperature on a given day (Tanner & Árvai, 2018; Taylor et al., 2014; Weber, 2016). Some studies have shown broad age differences in perception of risk, with older adults expressing more skepticism about climate change than younger adults (Akerlof et al., 2015; Weber, 2016). Perceptions of who should act to address climate risks, whether long-term global warming or immediate risks of flood or wildfire, vary too. For example, a 2012 survey of 961 homeowners in England and Wales, where flooding threatens one sixth of properties, found that respondents were aware of risks but largely perceived the problem as one for the government to solve (Bichard & Kazmierczak, 2012).

Implications

Understanding these factors of exposures, sensitivity, adaptive capacity and overall vulnerability as they are moderated by the residential setting can help inform planning and public policy. Knowledge of older adults' particular vulnerabilities could inform climate response plans—and deeper understanding of older adults' attitudes toward climate response could help policymakers and planners craft methods of outreach to involve them in plan making. Better data on older adults' housing, particularly its susceptibility to climate risks and the extent to which older

people are modifying (or are willing to modify) their homes in response to these risks, could help target programs designed to retrofit homes, reduce energy insecurity, and increase personal safety. Understanding these challenges can help tailor messaging and allocate resources to enhance safety and support in housing, neighborhoods, and communities across the rural-urban spectrum.

This paper has focused on older adults' risks of harm from climate change rather than their willingness to take personal or political action to mitigate greenhouse gas emissions. Yet there are age differences to consider here too, with evidence that older adults are less likely to engage politically or socially around climate change (Tyson & Funk, 2021).

Conclusions: Answers to key question

This paper set out one key question: How might the location and character of housing and neighborhoods where older people live aggravate or ameliorate the effects of climate change on their wellbeing? We have proposed that the residential setting at three scales moderates older people's vulnerability to climate change through their exposure, sensitivity, and adaptive capacity. We have drawn on the small existing literature at the specific intersection area of climate change, aging, and residential setting, and used separate work on older people's characteristics, housing and aging, and the effects of climate change to infer the situation of older people.

It is clear that older people have specific challenges related to climate change to do with their individual and social circumstances and physical settings. They may have moved to coastal

regions with good weather that are now vulnerable to hazards. In their neighborhoods and regions, they may be exposed to new threats from heat to dust at a time of their lives when they are becoming more sensitive to such irritants. They may live in older housing that is less well maintained or lacks modern materials able to withstand changing conditions.

In the remainder of the paper, we turn to the implications of this study in terms of where more research is needed to better formulate adaptation planning, design, and policy for climate change to be age sensitive. Of course, as we have shown in the earlier part of the paper, much is already known, and steps could be taken to reduce vulnerability for older people. But there are still key gaps (See **Table 3**).

INSERT TABLE 3 ABOUT HERE

A first gap is in the understanding of the specific vulnerabilities and risks older people in particular face by their residential setting. Of the many reports on climate change risk, few disaggregate by age. Yet age is a key factor in people's sensitivities and capacity to adapt and bounce back. Research expanding on the intersection of climate, aging, and residential setting could yield greater insights into how to reduce older adults' risks and enhance their adaptive capacity.

A second gap is in understanding the disparate exposures, sensitivities, and potential for adaptation within the older population**.** Obviously older people differ by income, race, and ethnicity, and while these are common factors examined in housing research, policy, and

planning, how they manifest in older people in the context of climate change could be better understood. People who have faced lifetimes of disparities in access to healthcare, employment, and housing may have poorer health in older age that increases their sensitivities to climate risks and fewer resources with which to address them. Many middle-income older people live in areas that are disaster prone and may lack the staff support available to people living in publicly-subsidized housing. There are many such variations.

A third gap is in knowledge about how older people respond to information about climate change risks. Policy implementation needs cooperation from those that are its targets. More insight is needed into the kinds of information and communication methods that are most effective in conveying risks to older adults and encouraging them to develop personal plans, retrofit homes, and participate in advocacy for climate mitigation and response planning. Part of this must involve unpacking who makes decisions about older people's housing, location, and neighborhood activities. Policymakers may assume adults are decision makers, but as people grow older some decision making is often transferred to others such as family members; for some, housing managers play a pivotal role here. Thus information may need to be targeted differently depending on population and setting.

A fourth gap is in knowledge about which older adults are most likely to engage in adaptation behaviors in the face of climate change. Perhaps it is those who have more financial resources, but this may not be the case as can be seen in the cases of wealthier people moving to more vulnerable locations due to natural scenery, such as barrier islands or wild-fire prone areas. Are

some kinds of private renters more vulnerable than others, for example, those with small-scale landlords who may themselves be unprepared?

Finally, there are gaps in understanding how agencies, housing providers, and others are developing policy responses and programming to deal with the climate change threat for older people. Is this a priority for offices for aging or public housing authorities? Are organizations involving older people in planning and policy development? Are information systems considering older people's needs from local government analytics to the many "best places to age" indices? Research could identify both good practices and common institutional blind spots.

Climate change's effects will be an ongoing challenge for urban planning and policy, a phenomenon colliding with an aging population. Addressing the research gaps in knowledge about older adults' unique risks based on where they live, their responsiveness to information about those risks, and their capacity to respond can help urban planners and policymakers to develop effective interventions to improve adaptation in an aging population.

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Declaration of Interest Statement

The authors report there are no competing interests to declare.

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Table 1: Older Adults Are Particularly Susceptible to Climate-Related Health Risks

Health Threats	Source	Risks more likely to be faced by older adults than other groups	Citations
Respiratory illness/ disease	Air pollution from rising temperatures; particulate matter from wildfires; increased allergens from changing seasonal patterns; particulate matter from wildfires; mold/mildew in homes after severe storms and floods	Older adults are more likely to have respiratory disease and are more susceptible to respiratory illness; pollution may keep older adults from participating in outdoor social activities	1, 2, 5, 7 2, 8, 12, 16
Heat-related illness	Extreme heat events create risk of heat exhaustion, heat stroke, confusion, renal issues, respiratory disease, and death; higher temperatures in general may discourage outdoor activity	Changes in thermoregulation with age can increase vulnerability to heat; older people also have high levels of diabetes, respiratory, and cardiovascular diseases that increase heat; use of some medications can also increase sensitivity to heat	1, 2, 3, 4, 5, 7, 10, 11, 12
Injury	Severe weather events (e.g., hurricanes, floods, extreme cold) and wildfires pose risk of personal injury and death	Higher rates of functional and mobility limitations make older adults more susceptible to injuries during extreme events, as well as in periods of evacuation and recovery	1, 5, 8, 9, 12, 17
Infectious disease	Vector, food-borne, and water-borne diseases pose risk of illness due to contaminated food and water	Older adults may be more vulnerable to gastrointestinal illness; older adults with comprised immune systems can be more susceptible to vector-born disease	1, 2, 8, 12
Treating acute and exacerbating chronic disease	Disruptions to infrastructure can impede access to medical care and therapies for existing disease, while particulate matter resulting from wildfires and water contamination after flooding may increase the risk of certain cancers	Older adults are more likely to have care needs that might be disrupted by extreme events and power outages, or to require special equipment that presents challenges during evacuation; older adults have greater vulnerabilities to chronic illnesses like cancer	8, 9, 13
Mental health	Peri-traumatic stress (experienced during or immediately following natural disaster), loss of property, and temporary or permanent displacement operations, can contribute to emotional distress, depressive symptoms, and post-traumatic stress.	Some studies have suggested that air pollution is a potential risk factor for cognitive decline; research also suggests older adults have higher rates of untreated depression that can lessen adaptive capacity; on the other hand, older adults may have stores of resilience that allow them to cope with disasters	1, 5, 6, 7, 12, 14

Notes: 1. (Gamble et al., 2013) 2. (Bunker et al., 2016) 3. (Kenny et al., 2010) 4. (Åström et al., 2013) 5. (McDermott-Levy Ruth et al., 2019) 6. (Heid et al., 2017) 7. (Clayton et al., 2017) 8. (Prohaska & Peters, 2019) 9. (Román et al., 2019). 10. (Carnes et al., 2014), 11. (Kovats & Hajat, 2008) 12. (Crimmins et al., 2016) 13. (McGuire et al., 2007) 14. (Merdjanoff et al., 2019) 15. (Spengler, 2012). 16. (Filiberto et al., 2009) 17. (Carter et al., 2016)

Table 2: Potential Effects of Climate Change on Housing

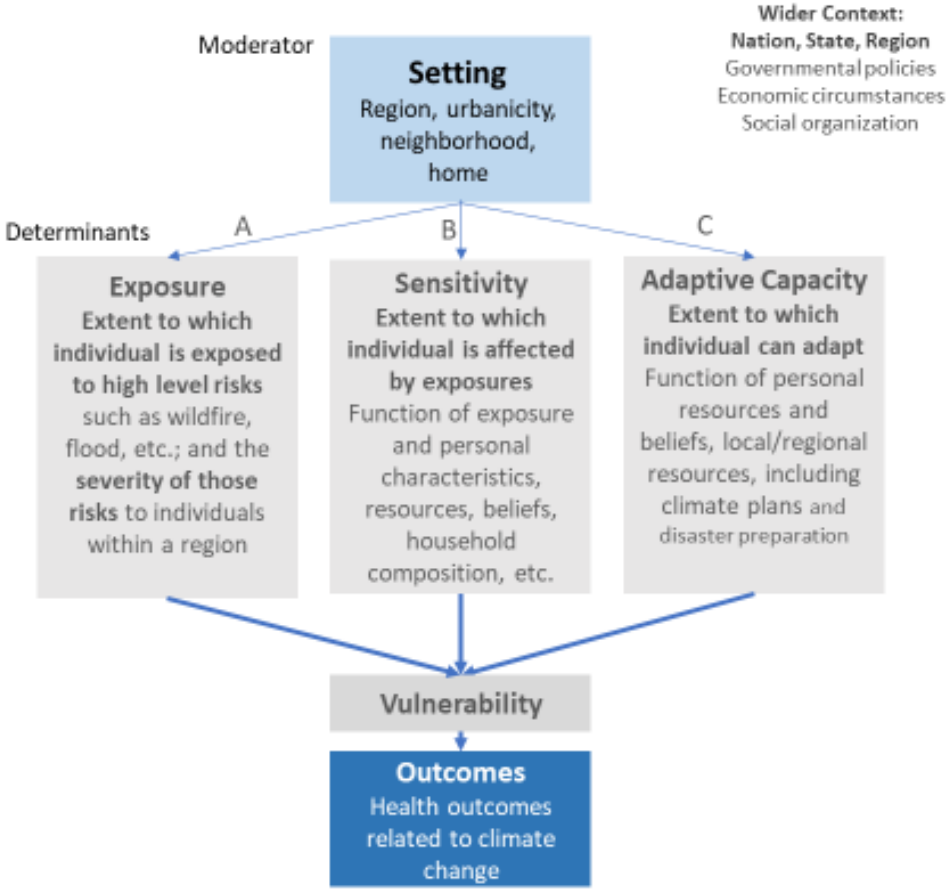
Risk	Possible Effects on Home	Risk to Occupants
Rising temperature	Impact on external surfaces and thermal performance of building. 1	Respiratory and heat-related illness from poor thermal regulation of home
More intense weather events and fluctuation of all kinds	Problems with electricity supply, diminishing building material durability, extended internal occupancy	Illness and disruption to medical care from poor indoor air quality experienced during prolonged time indoors, power outages, displacement
More intense Rainfall	Greater intensity of runoff, issues of structural integrity, drainage, opportunities for capturing rainfall. 1	Injury if structural integrity compromised, respiratory issues and injury from indoor flooding, displacement
More frequent/ intense cyclones/hurricanes/tornadoes	Greater strain on building material fixtures, claddings and fasteners; greater wind loading requirements. 1	Injury, displacement
More frequent Flooding	Sea level rise leading to coastal and inland flooding; more coastal salt spray; water damage to building contents; contamination from sewage, soil and mud; undermining of foundations. 1	Infections disease from water and vector-borne illness, injury, displacement
More fire events	Total or partial fire damage; smoke and water damage, decreased air quality from particulate matter (wildfires). 1	Injury, respiratory illness, displacement
More hailstorms	Impact damage (mostly roofs, guttering, windows) and subsequent rain/moisture penetration. 1	Injury, respiratory illness, displacement
Increased humidity	Mold, condensation, decreased thermal performance of building. 1	Respiratory and heat-related illness
Decreased humidity	Higher risk of fire. 1	Injury, displacement
Increased Drought	Problems with water supply. 2	Water-borne illness
Outdoor air quality (allergens and vector-borne disease)	Internal air ventilation (e.g. not opening windows)	Respiratory illness, heat-related illness, vector-borne disease illness
Increased pests (rodents, termites, mosquitoes, etc.)	Indoor environmental hazards and occupant disease, structural deterioration	Respiratory and vector-borne illness, injury

Source: Adapted from 1. (Snow & Prasad, 2011), 2. (Horton et al., 2010)

Table 3: Gaps in Research on Residential Setting, Aging, and Climate Change

Major Gap	Specific Research Gaps
Older adults' vulnerabilities to climate change as moderated by residential location	Age-specific studies on exposure, sensitivity, and adaptation by residential setting (gap 1) Disparities in exposure, sensitivities, and potential for adaptation including by race/ethnicity, income, household type, and resource availability (gap 2)
Older adults' responses to climate change risks	Older adults' responses to information on climate change, including relocation, including effective information and delivery methods on risks, personal preparation, home retrofits, advocacy (gap 3) Which older adults are more likely to respond to climate risks, including by income and tenure (gap 4)
Centering older adults' vulnerabilities and needs in climate action planning	Prioritization of older adults' needs and vulnerabilities in aging, housing, and/or climate plans (gap 5) Inclusion of older adults in planning processes (gap 6) Extent to which climate risks are included in materials designed to guide older adults' housing/location decisions (gap 7)

Figure 1: Residential Setting as Moderator of Climate Change Threats



Source: Adapted from Crimmins et al. (2016) by the authors.