Climate change, housing, and health:

A scoping study on intersections between vulnerability, housing tenure, and potential adaptation responses

FINAL REPORT

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NSW Adaptation Research Hub

The University of Sydney and the NSW Department of Planning, Industry and Environment

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Executive Summary

Climate change is bringing rising temperatures, more heatwaves, less predictable rainfall variability, as well as more frequent and intense storms, floods, droughts and bushfires. These expected changes present multiple threats to human health, particularly for vulnerable populations with existing health conditions or risks. Appropriate and affordable housing can help mitigate these risks. Houses can be better insulated for thermal performance, trees can provide canopy shading, reliably safe and palatable water can alleviate hot bodies. Uniting these disparate issues, is that of growing housing unaffordability across Australian cities and regions. These further expose many vulnerable groups to increased climate risks due to inadequate and poorly maintained housing; and in some cases, no housing at all.

International research suggests that the geography of exposure to climate risk often mirrors the geography of existing social disadvantage. In Australia, studies of projected climate change impacts show that heat risk also coincides with spatial patterns of relative socio-economic disadvantage, with lower-cost housing often located in areas more exposed to extreme weather events. Fire risk is potentially more indiscriminate, although the ability of victims to recover following housing losses or to deal with rental displacement, accommodation shortage, or increased insurance premiums following fire disasters, will also stratify according to income and place.

Taking this existing knowledge as its context, this project conducted a scoping study of the extent to which insecure, unaffordable or marginal housing significantly exacerbates residents' vulnerability to climate change. Funded by the NSW Department of Planning, Industry and Environment, as part of the New South Wales (NSW) Adaptation Research Hub within the University of Sydney, it brings housing more clearly into assessments of climate change vulnerability, and identifies key priorities for intervention.

The project's primary findings are that insecure, unaffordable and marginal housing significantly increase residents' vulnerability to the health risks arising from climate change. Vulnerability to extreme weather events is exacerbated by:

- dwelling structure (e.g. poor thermal performance, under-engineered for new threats);
- tenure (e.g. those living in boarding houses, social housing, or renting in the private market have limited ability to adapt their dwellings, a limited ability to persuade landlords to make modifications; and are be more vulnerable to displacement if their homes are damaged by a natural hazard such as flood, storm, or fire);
- dwelling location (lower cost housing is often located on land that is more vulnerable to extreme weather events or which is less accessible to services and transport);
- social isolation, lack of connectedness, or unfamiliarity with the local area and emergency protocols / responses; and

- underlying health conditions of individuals, including predisposing risk factors such as age and or disability.

In identifying and responding to these housing and health related risks associated with climate change; it is important not to pursue 'mal' adaptation measures which themselves contribute to global warming. Mitigating, or addressing the underlying causes of climate change by reducing greenhouse gas emissions, is beyond the scope of this study. However, in identifying priorities for further research and policy development, we emphasise the need for housing/health adaptation responses to be situated within wider frameworks for climate mitigation. This will require deep, integrated approaches across the multiple sectors responsible for housing, health, community services, and infrastructure and across all three tiers of government.

Priorities for further research and policy development identified in this scoping study include:

- Improved and interconnected geospatial data sets which overlay physical risks (e.g. heat, bushfire, flood affected areas) against housing and health data to identify overlapping clusters of vulnerability. This work must recognise that historical data on areas subject to natural hazard needs revision in the light of climate change.
- A review of existing state/local public health and emergency information and response strategies, with particular consideration of targeted information for individuals and households living insecure or inadequate accommodation, and or with particular health vulnerabilities; as well as their care givers, housing providers, and community service agencies.
- The development of more fundamental changes to the built environment through housing and planning sector responses which:
    - Improve the thermal performance of new housing development; reduce energy requirements; and embed energy/water efficiency and generation/collection within building and neighbourhood design (lowering energy and water costs and reducing greenhouse gas emissions generated by the residential sector);
    - Include wider public realm strategies to reduce urban heat, and provide access to cool spaces, shading, water, and services in all communities, including accessible infrastructure / facilities able to offer respite during extreme weather events.
    - Implement specific 'resilience' retrofitting strategies for the private/social rental sectors, with particular emphasis on its thermal performance and adherence to fire/storm safety standards, and strategies to address heat and other climate related risks faced by residents of non-standard and informal housing (e.g. caravan parks/manufactured home estates; boarding houses).

Beyond these measures, expanding access to social housing and to affordable, secure accommodation in the private sector is a primary strategy for reducing health related vulnerabilities to climate risk. This will imply redirecting or better targeting Commonwealth and state housing budgets towards expanding the social housing sector and towards

incentivising affordable new housing supply for low cost home ownership and private rental. State reform of private rental laws, to improve tenure security, and better regulation of the condition and quality of rental housing would also reduce housing-related vulnerabilities of low income renters.

Finally, an important insight of this project has been an identification of the *lack* of policy frameworks regarding how these issues of housing, health and climate change are intimately connected. The coordination that will be increasingly required – across different communities, organisations, and agencies – can only begin if this foundational interconnectedness is recognised and acted upon. The severe risks associated with extreme weather events and climate change more generally means that integrated action across housing, health, community and planning agencies to reduce climate vulnerability, alongside mitigation efforts, has become an urgent priority.

Introduction

Housing is one of the important factors influencing the extent to which vulnerable populations can adapt to risks associated with climate change. Vulnerable populations here include the elderly, youth, isolated, disabled, chronically or mentally ill and low-income groups. International studies demonstrate that these groups are particularly vulnerable to health risks arising from extreme weather events, not only for bio-physical reasons, but because of the limited capacity for those in vulnerable or unofficial tenure situations to modify their homes, and the higher climate exposure arising from overcrowded, inadequately maintained, or inadequate forms of shelter (Cutter and Finch 2008, Finch and Emrich et al. 2010, Gabriel, Watson et al. 2010, Molony and Goodman 2012, Maller and Strengers 2011). Vulnerable groups may also be harder to evacuate during emergencies.

Appropriate and affordable housing can help mitigate these risks. However, the chronic shortage of social and affordable housing supply means that many lower income groups are living in unaffordable or inadequate housing conditions which will likely exacerbate their vulnerability to climate risks. Furthermore, the intersections between housing need and climate vulnerability remain poorly understood. Relatedly, while much is known about the pre-existing health conditions which render individuals more vulnerable to extreme heat events (such as age, cardiovascular disease, kidney disease, diabetes, people with mental health problems), the additional issues of vulnerable households, with or without these known morbidities, is not configured into emergent climate-change related health policies.

Given the limited existing data on this important problem, researchers from the University of Sydney undertook an initial scoping study exploring the extent to which unaffordable, insecure or marginal forms of housing intensify existing climate related vulnerability. Our key goals were to identify particular risks associated with specific dwelling types occupied by high need groups in low cost social, private, rental and marginal forms of housing tenure; and thus to have housing conditions better considered in assessments of climate change vulnerability.

Using a housing typology which identifies likely vulnerable housing situations (specific dwelling types occupied by high need groups in low cost social, private, rental and marginal forms of housing tenure), the project investigated conditions of extreme heat alongside varying degrees of moisture (e.g. humidity) to explore particular risk profiles. Drawing from fieldwork interviews, formal consultation with housing workers, and the NSW Department of Planning, Industry and Environment's NARClim data[1], the project also mapped zones of climate vulnerability within NSW, including both climate projections and concerning housing scenarios, to identify priorities for further research, policy development and intervention.

[1] The **N**ew South Wales (NSW) and **A**ustralian Capital Territory (ACT) Regional **Clim**ate Modelling (NARCliM) Project is a research partnership between the NSW and ACT governments and the Climate Change Research Centre at the University of NSW. For more see https://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM

Despite the focus in this project on identifying the housing and health related risks associated with climate change impacts already underway; it is important to frame adaptation responses within an overall understanding of the strategies needed to mitigate global warming. This will require deep, integrated approaches across the multiple sectors responsible for housing, health, community services, and infrastructure and across all three tiers of government. In this context, this report summarises key findings, outlines areas for further consideration, and makes recommendations for developing appropriate communication strategies and policy interventions for improving adaptive capacity for those most vulnerable to extreme weather as a result of their housing and health conditions.

This study was funded by the NSW Department of Planning, Industry and Environment as part of the NSW Adaptation Research Hub within the University of Sydney, with NSW Health as a partner research organisation.

Definitions and Scope

Research question

The overall research question driving this study is: to what extent does unaffordable, insecure or marginal forms of housing exacerbate existing climate related vulnerability? 'Extent' is approached here in semiotic and not epidemiological terms: what kinds of concerns do members of the public and relevant service providers nominate when housing, health and climate change are discussed?

Mixed methodologies

Mixed methodologies were used across three stages of the scoping study. **Stage one** comprised a review of previous research undertaken by research or policy bodies in Australia and internationally, to establish the current "state of knowledge" on the intersections between climate vulnerability, rental/marginal housing, and health.

Stage two consisted of meetings with key housing and health sector professionals to identify existing knowledge 'on the ground' and priority foci for investigation. Fieldwork was then conducted in three case study areas: Sydney metropolitan area, the Northern Rivers region, and the Orana region of Northwest NSW. These areas were chosen for their general representation of metropolitan, coastal and inland infrastructural and projected climactic conditions. In-depth interviews were held with 20+ people, including housing workers, tenancy advocates, council workers, community leaders and Indigenous elders. These research participants not only provided rich information on the intersections of insecure housing and climate vulnerability, but a means of gathering this knowledge without exposing already vulnerable residents to risk of further harm (e.g. legal, socio-emotional or other harm that may result from publicity and probing).

Transcribed and analysed for themes, the interview data informed **Stage three** of the project. This comprised the development of a housing typology; the mapping of hotspots of

climate vulnerability across NSW; and the depiction of housing/climate scenarios. Stage three visualises much of the project's analysis, constructing schemas which can be used to identify particular vulnerabilities and priorities for intervention.

Heat and extreme weather

While we acknowledge climate change has diverse impacts, the project had a primary focus on heat, which was seen by the funding partners to be a key priority for initial research and analysis. This said, interviews frequently generated questions of other extreme weather issues (heavy storms and rain, threats of inundation, water insecurity, drought), and thus these issues are also canvassed in our report. Indeed, it is difficult to disentangle problems of heat from the wider weather patterns and effects associated with climate change. For instance the effects of heat cannot be studied in isolation from consideration of humidity and mould, of aridity and drought, of car dependency and urban heat effects.

It should be noted that the research took place before the unprecedented fires beginning September 2019 and continuing into 2020. Sadly, such devastating events further showcase the urgency of policy attention to affordable secure housing, people's health and wellbeing, and the pressures of climate change.

With its focus on the connections between housing, tenure type, health and heat, this report does not explore the likely impacts on health service demands, nor the resources, workforce, biosecurity and infrastructure challenges that climate change specifically poses for the health sector.

Outline of this report

The report is divided into four sections.

Section one draws on international and Australian literature to outline the potential intersections between climate change, human health and housing. It begins with a discussion of projected climactic conditions for NSW, establishing the context for the empirical case study research. It continues with an explanation of the health-related risks arising from anticipated changes in Australia's climate, and how these are exacerbated by pre-existing vulnerabilities relating to age, existing health conditions or predispositions. Finally, it turns to the many ways in which housing affects human health.

Section two describes and reports on the NSW qualitative case study research. It discusses the need to protect residents of precarious housing from further exposure and the research decisions taken to ensure this. It presents composite portraits from interviews with housing and community workers to suggest typologies of at-risk housing in NSW.

Section three brings these findings together: firstly as a typology of housing related to climate risks to human health; secondly by mapping 'hot spots' of vulnerability across NSW.

This section provides a series of schemas through which housing and climate-related health risks may be anticipated, as a means of identifying priorities for intervention.

Section four outlines areas requiring future research, and recommendations for appropriate communication strategies and priority policy interventions for improving adaptive capacity for those most vulnerable to extreme weather from their housing and health conditions.

An **Appendix** depicts concerning scenarios related to particular dwelling types and locations within current climate change projections, and the potential negative health outcomes that may result from these.

Section 1: Existing knowledge: national and international literature

Near and far future climate projections for NSW

Climate change will bring rising temperatures, more heatwaves, rainfall variability resulting in both drying and wetting scenarios, as well as more intense weather events such as storms, floods and bushfires to Australia (Commonwealth of Australia Productivity Commission 2012, Instone, Mee et al. 2015, OEH 2018).

In the **near future** (that is, by 2030), and conservatively estimated, temperatures are predicted to increase by between 0.7-0.9 degrees Celsius in most coastal areas (compared with the baseline period of 1990-2009), and at higher rates for inland regions (OEH 2018). Greater variation in temperature extremes is also likely, and the number of hot days followed by warm nights will increase. By 2030, Wollongong, Sydney, Newcastle, Coffs Harbour and Byron Bay are expected to experience an additional 5-10 days over 35°C each year; while inland towns such as Cobar, Burke and Moree will likely experience between an additional 10-20 days (OEH 2018).

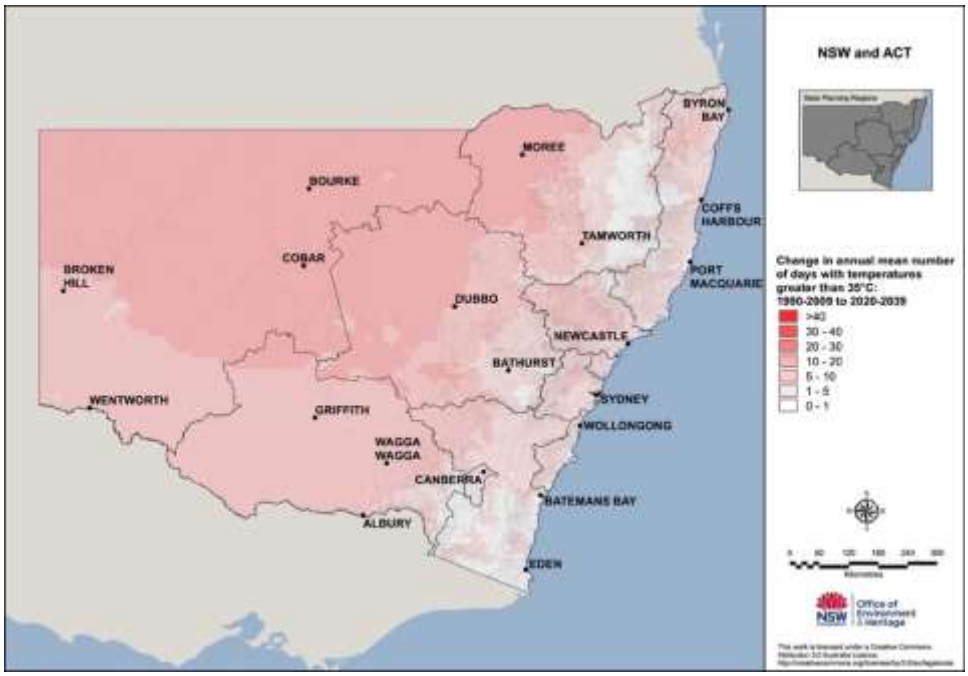


Figure 1 Near Future Maps (2020-2039) showing the change in annual mean number of days with temperature over 35°C (compared with 1990-2009). Source: NARClim dataset

Near future projections for precipitation indicate that north and north-western parts of the state will be more humid, while the south and south-west will be drier and will receive less rain. This will expose these regions to greater fire risk with associated extinction risks for many threatened species, alongside loss of livestock, business infrastructure and housing.

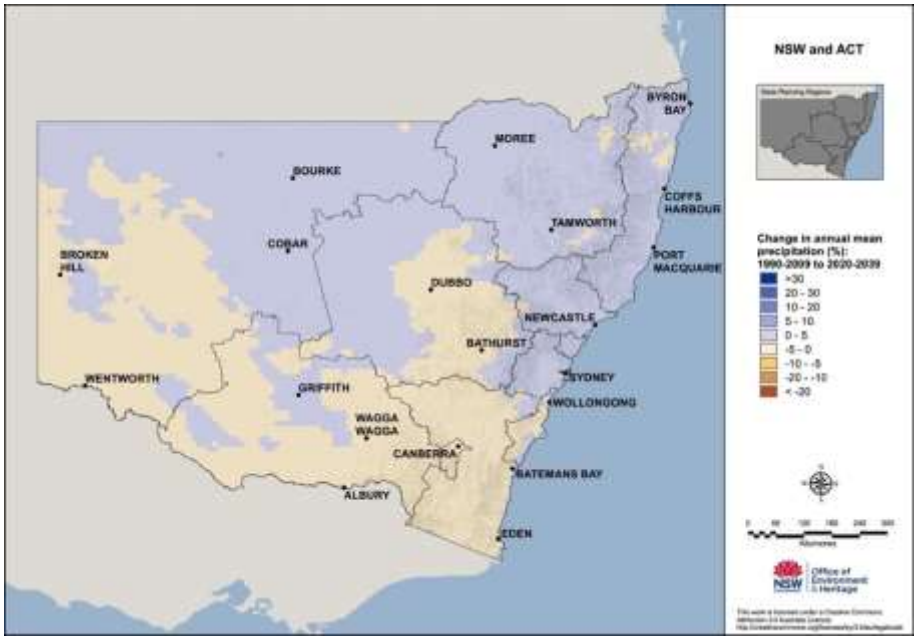


Figure 2: Near Future Maps (2020-2039) showing the change in annual mean precipitation (%) (compared with 1990-2009). Source: NARClim dataset

In the **medium-far future** (that is, by 2070), NSW coastal temperatures will minimally rise 2 degrees Celsius, while Northern inland NSW will rise by 2-3 degrees (compared with the period of 1990-2009) (OEH 2018). The greatest increases in the number of heatwave days per year are projected for the northern interior of the state (26-33 more days per year than during 1990-2009). Bourke and Moree will experience days over 35°C for an additional 40 days of the year, and thus will be the most effected towns in NSW.

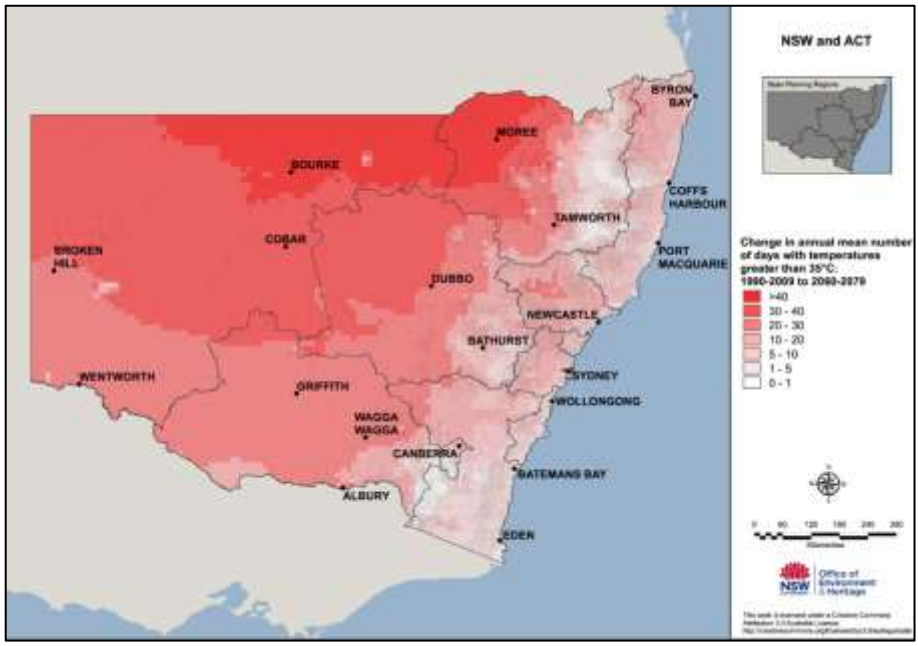


Figure 3: Far Future Maps (2060-2079) showing the change in annual mean number of days with temperature over 35°C (compared with 1990-2009). Source: NARClim dataset

Far future projections for precipitation indicate that while the towns of Bourke and Moree will become hotter, they will also experience increases in humidity.

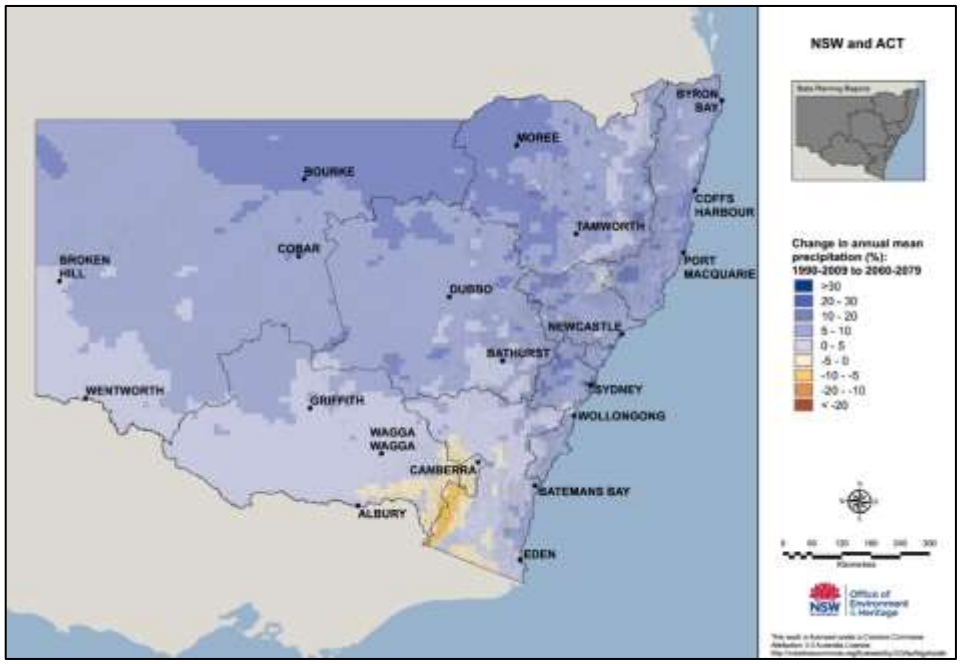


Figure 4: Near Future Maps (2060-2079) showing the change in annual mean precipitation (%) (compared with 1990-2009). Source: NARClim dataset

Changing land uses (ranging from overgrazing, conflicted policies on water management and fire hazard reduction through to low density urban to higher density urban emphases) will also exacerbate temperature changes. Population growth in cities is also likely to contribute to the urban "heat island effect," where urban environments emit and retain heat, which in turn increases demand for power and puts pressure on energy networks.[2]

Heatwaves are defined as a sustained period of high maximum and minimum temperatures. Extended heat periods can also reduce the windows available to conduct safe and effective hazard burning in pastures and woodlands, increasing the risk of high intensity fires. They are associated with a range of poor health effects, from heat stress, exhaustion and sunburn to kidney failure and heart attacks (Koppe, Sari Kovats et al. 2004). As well as these personal health risks (discussed further below), heatwaves also increase the risk of other extreme and life threatening events such as bushfires (OEH 2018). In urban fringe areas and in more remote locations fire seasons are likely to extend and affect new regions. In lower lying and coastal locations risks from storms and flooding will increase. Humidity is another aspect of heat which differs by climatic zone (Oppermann, Brearley et al. 2017), and heat-based climate impacts can be exacerbated by rising humidity.

These forecasts present many threats to human health, particularly for vulnerable populations with existing health conditions or risks. Appropriate and affordable housing can

[2] See Adapt NSW booklet, 'Urban Heat Climate Change Impact Snapshot'. Available at: *https://climatechange.environment.nsw.gov.au*

help mitigate these risks, particularly those arising from extreme heat events. However, growing housing affordability pressures in Australian cities and regions expose many vulnerable populations to increased climate risks due to inadequate housing.

Risk, vulnerability, and capacity to respond

Risk is an important concept for understanding climate change impacts. Two considerations – the level of probability that an event will occur, and the scale of impact arising – provide a basis for assessing risk (Voice et al. 2007). High probability of a particular event, combined with high potential impact, indicates a high level of risk. The relative costs and effectiveness of different adaptation measures are then able to be evaluated in determining how to respond to climate risk both through government policy changes and through individual actions. For instance, there are many adaptation measures which can be introduced to help manage the thermal performance and fire retardant properties of homes, making them more resilient.[3]

However, the capacity to respond to climate risks – for instance, by modifying homes to reduce exposure to high heat – differs across the population. Social and economic factors like income/financial resources, education, age, and health status, all influence resilience to climate risk, and the need for additional assistance. Both the very old and the very young, as well as people with a disability, have particular vulnerabilities to climate risk (Cutter and Finch 2008, Finch and Emrich et al. 2010, Few 2007, Rosenkoetter et al. 2007).

International research suggests that the geography of exposure to climate risk often mirrors the geography of social disadvantage. For instance, in their study of 'heat-related health inequalities' in Phoenix, Arizona, Harlan et al. (2006) found that lower socio-economic and ethnic minority groups were more likely to live in warmer neighbourhoods, and people in warmer neighbourhoods were more vulnerable to heat exposure because they had fewer social and material resources to cope with extreme temperatures. Similarly, statistical analysis of potential inequities associated with the distribution of urban tree cover in relationship to race/ethnicity and income, in seven cities across the United States (Baltimore, Los Angeles, New York City, Philadelphia, Raleigh, Sacramento and Washington, DC) found that income and urban tree cover were positively correlated (Schwarz, Fragkias et al. 2015), implying a neighbourhood wealth effect. Given the importance of tree canopies and vegetation for urban cooling, such studies highlight the socio-economic and spatial disparities in access to environmental amenities known to reduce heat risk.

Similarly, studies of projected climate change impacts in Australia show that geographies of heat risk may also coincide with spatial patterns of relative socio-economic disadvantage (VCOSS 2013). For instance, projections of temperature increases are higher in Western Sydney than in Eastern parts of the city (OEH 2014) where access to cooling breezes correlates with higher relative socio-economic advantage. Predicted urban expansion for Sydney will further amplify the felt effects of a hotter climate, reducing vapour pressure

[3] For an indicative listing of such strategies, see http://www.yourhome.gov.au/passive-design/thermal-mass

during the day and increasing temperatures at night (Argüeso et al. 2015), while also elevating perceived minimum temperatures throughout the year (Argüeso et al. 2014).

Health vulnerabilities, climate risk, and adaptation to protect health

Numerous studies have established the effects of weather and climate on health (Oppermann, Brearley et al. 2017). This evidence, which can be used to inform assessment of climate and weather-related health risks, must be interpreted in the light of projected climate change. In Australia, where heat exposure has killed more people than other natural hazards combined, rising temperatures associated with climate change are critical considerations when assessing potential health vulnerability to climate change (Oppermann, Brearley et al. 2017).

Individual as opposed to locational vulnerability to the health risks of climate change depends on the individual's health status, their understanding of risk, and their capacity to take adaptive measures to reduce exposure to the risk (Maller and Strengers 2011). Vulnerability to heat is highest for infants, the elderly, and those with chronic medical conditions. People with particular health conditions and risks, such as obesity and related diseases like type 2 diabetes and heart disease, are also especially vulnerable to the effects of hot temperatures (NSW Health 2016). Pregnancy and lactation can increase vulnerability to heat and effects such as dehydration. Australian studies have also shown that heat impacts on wellbeing, exacerbating pre-existing mental health conditions, and having negative effects on mood and quality of life (Oppermann, Brearley et al. 2017). Hospital admissions for injuries relating to assaults rise during periods of intense heat (Bambrick, Capon et al. 2011).

Vulnerability mapping

Identifying areas of high risk is one of the first steps to climate change adaptation. Over the past decade a series of studies have demonstrated potential approaches for mapping vulnerability to heat stress.[4] Using Melbourne as a case, Loughnan et al. (2012) used mortality and morbidity data relating to heat events to construct a 'vulnerability index' able to map and identify vulnerability to heat stress in the city. A key finding is that areas with nursing homes have higher rates of morbidity during heat. Heat exposure may also be a secondary risk factor for people displaced by other weather hazards such as floods and bushfires (p. 10).

In their detailed analysis of potential adaptation to climate risk in the low income housing sector, Barnett et al. (2013) identified variations in the thermal geography of four Australian cities (Adelaide, Sydney, Melbourne and Brisbane). The team used remote sensing data on heat, as well as maps of urban vegetation, and derived data on urban form (including

[4] For instance, Uejio et al (2011) have constructed vulnerability maps for Philadelphia and Arizona in the USA, using indicators relating to the built environment as well as socio-economic disadvantage. Johnson et al 2012 developed their own index called an 'extreme heat vulnerability index' (EHVI), drawing on data generated by the Chicago heat wave, such as census data, remotely sensed variables, and geocoded mortality data.

building density, land cover and housing types). The exercise then used demographic data of known heat risk factors (income, age, disability, education, age and social isolation) to identify whether heat sensitive populations reside in the most vulnerable locations of the city. The analysis found that low income households are concentrated in urban areas with the highest land surface temperatures, and that heat related health risk factors for these populations were correlated to these land surface temperatures (Barnett, Beaty et al. 2013). The study concluded that across all four Australian cities in the study, the hottest areas were also those with the highest proportions of low income residents. Typically, these were older inner city suburbs, with high residential densities and high proportions of impervious surfaces; and newer outer metropolitan suburban areas with lower net density but relatively larger homes and limited vegetation.

Adaptation

In their global review of the human health impacts of climate change, Smith et al. categorise adaptation responses as "incremental, transitional, and transformational" (Smith, Woodward et al. 2014, p. 733). Incremental approaches focus on improving public health and care services overall; transitional adaption efforts improve awareness of climate change risks, for instance through vulnerability mapping. Transformational adaption involves systemic change. This might include, for instance, changes to planning and design of the built environment which reduce urban heat effects; or anti-poverty measures which reduce and eliminate homelessness and related risks arising from inadequate housing.

Housing and health

The connection between poor housing and poor health has been established internationally by researchers in a range of interdisciplinary fields (Bentley et al 2011; Bonnefoy et al 2003; Evans 2000; Thomson et al. 2013). In 2018, the World Health Organisation (WHO) released a series of guidelines that provide international recommendations on how to improve housing conditions for better health outcomes (WHO 2018). These guidelines point to the relationships between:

1. Structurally deficient housing / Increased hazards and risk for injury
2. Poor accessibility / Risk of injury, stress, isolation
3. Affordability / Insecure Tenure / Stress
4. Overcrowding and Crowding / Increased risk of physical injury, social tensions, alcohol abuse and partner violence, exposure to air particulates, inadequate sanitation
5. Poor ventilation / Numerous non-communicable disease outcomes
6. Low and High Indoor Temperatures / Poor respiratory and cardiovascular outcomes

The WHO guidelines acknowledge the increasing importance of housing to health due to demographic and climactic changes. This work builds upon that of the Australian not-for-profit, Healthabitat, and the latter's long history of survey-fix work targeting what they term the 'health hardware' inside homes. Health hardware references safe electrical systems,

toilets, showers, taps, kitchen cupboards and benches, stoves, ovens and fridges (Pholeros et al. 2013). In its work assessing and fixing the health hardware of houses in Indigenous communities, Healthabitat have identified nine Healthy Living Principles (HLPs) which, if enabled with functioning household infrastructure, contribute most directly to maintaining health and preventing infection (Healthabitat 2018a, 2018b). Thermal performance is one such HLP. In partnership with the Housing for Health Incubator at the University of Sydney, Healthabitat has also recently begun to collect data with climate change in view, updating its *Housing for Health – the Guide* handbook to better anticipate current and future heat, water and energy challenges. These include the increased range of vector borne and fungal diseases and questions of locational viability, given increased water insecurity (Lea and Grealy et al. 2018).

Housing affordability and health

Lack of access to affordable housing is known to exacerbate existing, and to increase the risks of new, health conditions (Baker, Mason et al. 2014).

Definitions of affordable housing incorporate cost, adequacy, and appropriateness, having regard to household characteristics and societal norms. In Australia, a housing cost relative to income definition of housing affordability is commonly used, with housing considered to be affordable for low and moderate income earners if costs are up to 30% of household income (Gurran and Bramley 2017).

However, this measure of affordability is often criticised because it does not consider the residual funds available to households once they have met their housing costs. For instance, very low income earners may have insufficient remaining funds to pay for adequate food, medicine, transport, power, or clothing (Kutty 2005). The quality of the housing – which should offer adequate facilities (such as the means to wash both bodies and clothes, to prepare food and remove waste appropriately), privacy, safety and security – is another dimension. Appropriateness is also critical.

This can be defined in terms of:

- the dwelling characteristics (e.g. around such as issues as accessibility, thermal performance, building physical condition and maintenance)
- size relative to the household, and
- location relative to transport, employment, services and social networks.

Unaffordable, inadequate, or inappropriate housing can undermine health and wellbeing in many different ways (Oppermann, Brearley et al. 2017). Low income earners and those with existing vulnerabilities to disease such as the elderly and young children, are most vulnerable to poor housing conditions such as overcrowding, disrepair, damp and mould, indoor pollutants, and inadequate thermal protection. Each of these health risks derive from the physical condition of the dwelling and are exacerbated by heat and humidity.

There are other health risks which can arise due to the location of housing and the design of the surrounding built environment and neighbourhood setting. For instance, those living in areas with low walkability and poor accessibility to public transport, are vulnerable to issues arising from car dependency in obesogenic environments, including inactivity and social isolation. The location and accessibility of housing to health services, schooling and other community facilities, such as emergency shelters or swimming pools, also have important bearings on health.

Household characteristics and housing vulnerability

Many health risks arising from unaffordable or inadequate housing compound existing vulnerabilities such as age, or disability. For instance, Baker et al (2014), demonstrate a 'bi-directional relationship' between housing affordability and health (using a definition of health which includes mental health), drawing on data from the Household, Income and Labour Dynamics in Australia (HILDA) survey. Among other findings, the authors find that 'almost half of older renters live in unaffordable housing, and children living with a single parent are seven times more likely than children living with two parents to be in unaffordable housing' (2014, 82). Particular housing related vulnerabilities are experienced by very low and low income earners, older renters, lone persons, and sole parent households (Baker and Beer 2007). The difficulties of meeting housing payments both increase the risk that lower income groups will be forced to live in inadequate dwellings, and mean that vulnerable households may have insufficient "after housing" funds to pay for essentials such as food, power, mobility aides or medical treatment.

Household vulnerability and tenure

Housing tenure is an important concept for understanding household vulnerability, often determining the extent to which householders can adapt their dwelling and so mitigate the effects of climate change. Formal housing tenures reflect different levels of control over terms of occupancy and modification of a dwelling. Those in rental tenure generally have less control over their dwelling or the length of occupancy than those living in their own home. At the extreme end of housing need, people who are homeless, including people who are couch surfing, have no tenure at all.

Those living in crisis accommodation or in boarding houses, have limited and generally short term tenure. Different forms of supported accommodation (for example, group homes for those with a disability, or for the aged), may offer longer term tenure. Residents of social housing generally have more security of tenure than those in the private sector, and will be paying a lower proportion of their income on housing. However, they do not necessarily have a greater ability to modify their dwelling. This matters in terms of managing dwellings to improve thermal performance.

Renters in the private sector face particular barriers to adapting their properties for climate resilience (Gabriel, Watson et al. 2010, Instone, Mee et al. 2015). Lower income owner-occupiers may also lack the capacity to adapt their dwelling in anticipation of extreme

weather adaptive capacity (Moloney and Goodman 2012). New mortgagees may face greater risk of energy stress (economic risk), heat stress (biophysical risk), and lack of access to public transport (social or infrastructural disadvantage), all of which increase their vulnerability to climate-related negative health effects.

People living in informal housing – such as in overcrowded share households, and/or in dwellings that do not conform with housing regulations are also exposed to health and other climate-related risks. Such householders 'fly under the radar' of detection and the invisibility of informal housing makes it difficult to address these dangers (Gurran et al. 2019).

Tenure insecurity experienced by low income renters is exacerbated during natural emergencies, such as storms, floods, and bushfires which cause significant property damage. Post disaster housing shortages are likely to translate to long term displacement for low income renters unable to find alternative accommodation (Victorian Council of Social Services (VCOSS) 2013).

Household vulnerability and dwelling characteristics

Particular dwelling characteristics exacerbate particular types of health risks. With specific reference to heatwaves, the Victorian Council of Social Services (2013, p. 5) has identified particular risks arising in relation to:

- 'public housing properties, rooming houses and caravans that were described by staff as "hot boxes" for residents who had no access to cooling or cool areas'
- Poor quality rental housing where landlords did not allow air-conditioning or fans because of operating costs
- Lack of access to drinking water, particularly for those people that are homeless and sleeping rough, as well as those living in accommodation that restricts access to kitchens and bathrooms.
- Lifts not functioning in high rise apartment building because of heat related power shortage
- Vulnerable people needing to walk in extreme heat, due to adequate public transport; and,
- A lack of monitoring of vulnerable people including people exposed to the elements due to homelessness.

Many low income groups cannot afford or are not permitted by landlords to install or use heating, air conditioning or fans, and experience financial hardship due to rising energy prices. Studies suggest that rising levels of "energy stress" will contribute to seasonal increases in rental evictions in Australia and elsewhere, with low income households unable to maintain the dual burdens of high rent and power bills (ACOSS and Brotherhood of St Laurence 2018). Poor thermal performance of dwellings and the energy costs of cooling affect lower income Australians disproportionately (ACOSS 2013; St Vincent de Paul and Alviss Consulting 2016; Azpitarte 2015).

Typologies of housing vulnerability

When considering the different vulnerabilities that arise from housing, researchers have developed tools for conceptualising the multiple dimensions of housing need or deprivation. For instance, criteria for the structural features of the dwelling ("habitability"); privacy and control over one's space, and security of tenure provide categories for identifying housing types along a continuum of need (Amore, Viggers et al. 2013, Amore 2016). There are close connections between these categories and definitions of homelessness and housing exclusion which include physical dwelling, legal, and social dimensions (Busch-Geertsema 2010).

The European Typology on Homelessness and Housing Exclusion (ETHOS) distinguishes between housing types which are "roofless" (people sleeping rough outdoors or staying in emergency overnight shelters); "houseless" (living in homeless accommodation or accommodation for new immigrant arrivals; and people about to be released from institutions); "insecure" (people staying temporarily with family or friends; at risk of eviction; or living under the threat of violence); and "inadequate" (living in nonconventional structures like mobile homes; unfit housing; or extreme overcrowding) (Busch-Geertsema 2010).

Intersections between heat, climate risk, and housing vulnerability

In examining the heat risks experienced by social housing tenants and identifying potential adaptation pathways, Barnett et al. (2013) estimated thermal performance and the indoor environment of homes. The study identified ten common housing types across the four Australian cities in the study, located in all the major climatic zones of Australia as defined by the national construction code[5], and estimated thermal performance of these housing types in the specific climate zone, and under projected climate scenarios (using a "Discomfort Index").

The ten housing types identified are characteristic of the different housing designs, construction methods, and materials used in social housing and also typical of the housing available to low and moderate income groups in the private sector.

[5] The National Construction Code of Australia (NCC) is a nationally agreed code for uniformity in building to address basic health and safety standards in construction and design, based on classifications of building use. All State and Territory planning laws enforce the NCC as conditions of planning approval for new development.

They include:

Detached dwellings	*Attached dwellings / apartments*
1. Concrete slab, brick veneer (older style) 2. Low set subfloor, brick veneer 3. Low set subfloor, fibro / weatherboard 4. High set subfloor, brick veneer 5. High set subfloor, fibro / weatherboard 6. Concrete slab, brick veneer (current style)	7. Low rise 1 bedroom flats 8. Low rise, 2-3 bedroom flat 9. High rise flat, 1 bedroom 10. High rise flat, 2-3 bedrooms

Source: Barnett, Beaty et al. 2013, pp. 16-18.

From these basic categories, additional considerations, including the orientation of the dwelling on the site, and the location of the apartment, could have significant implications for thermal performance. The study found that:

- Houses in climate zones with hot and humid summers are the most vulnerable
- Some dwelling types vary more than others, but variation in thermal performance is largely a question of building quality (orientation, building age) rather than the type of housing
- Retrofitting programs could effectively address thermal discomfort in temperate climates but would be inadequate in hot and humid climatic zones, where air conditioning is likely to be required.

By focusing only on homes within the social housing sector, one of the key household vulnerability considerations – insecure tenure – was not confronted in this study. For social housing providers, the cost of retrofitting actions may be high, but will be offset by increased asset value across the portfolio and potentially in savings to tenants in lower power bills. However, there are significant barriers associated with funding and implementing retrofitting programs for the private sector. Further, accommodation with a high thermal performance is likely to attract a higher rent.

Residential neighbourhood design and retrofitting

Adapting the built environment – particularly residential neighbourhoods – to reduce exposure to rising temperatures as well as the compounding urban heat island effect – may also represent significant benefits for lower income and vulnerable populations. Strategies for Sydney's central area, Parramatta, and western suburbs could include:

- Introducing high albedo (reflective) paving and permeable paving
- Increasing the tree canopy
- Increased shade structures
- Green and cool (reflective) roofs, and more extensive use of solar panels
- Green and "living" walls

Areas of surface water and evaporative cooling technologies (such as misting fans as water features, used in conjunction with shade trees) can also be added, although evaporative cooling is only effective in days of low relative humidity (Osmond and Sharifi 2017, p. 43).

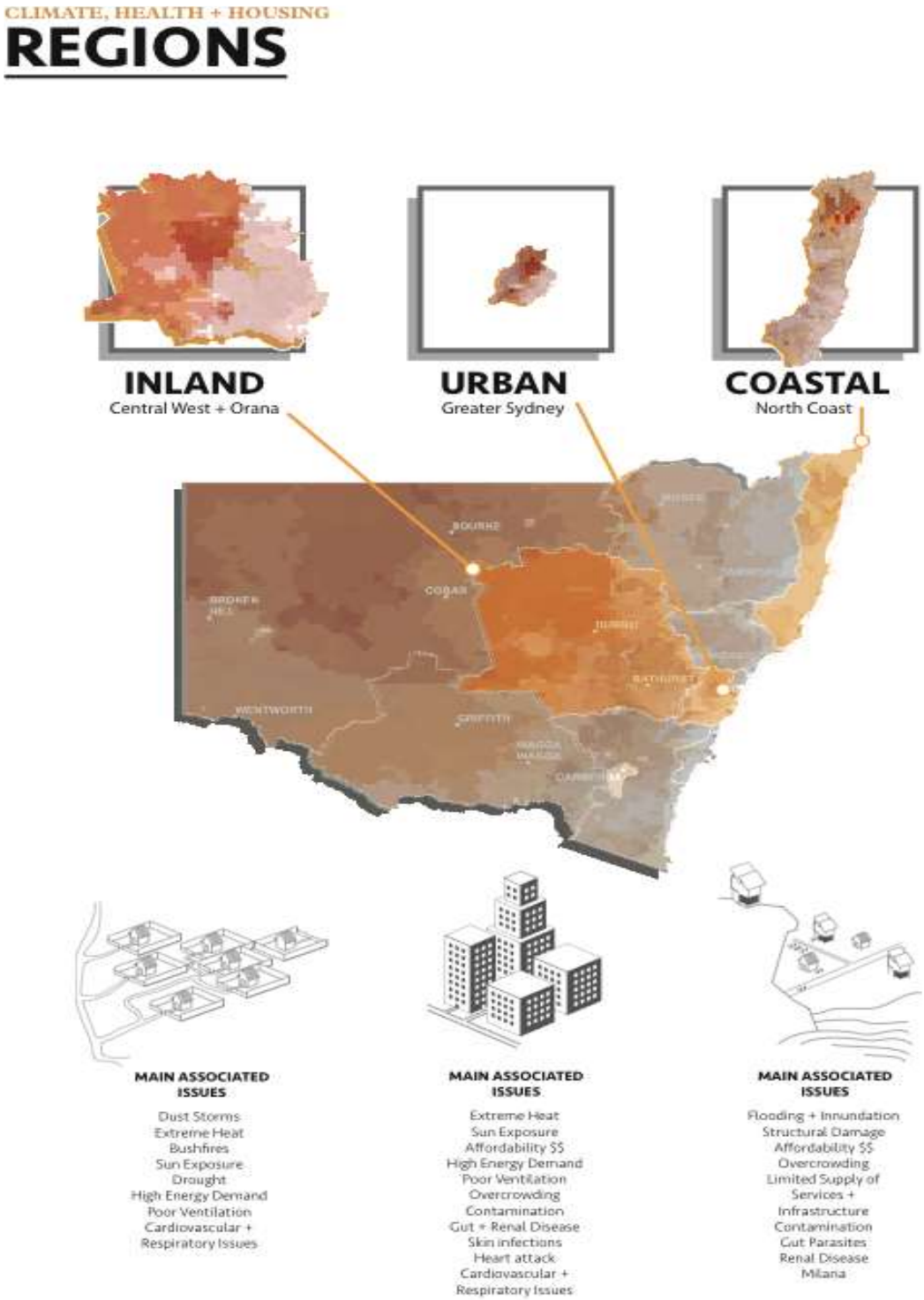
These strategies both improve resilience to the effects of climate change which are already underway, while also reducing overall contributions to greenhouse gas emissions by lowering energy requirements and reducing car dependency, with cooler, shaded, and naturally vegetated environments more amenable to walking and cycling.
In addition, it is important that more explicit consideration of the important role played by facilities such as libraries and shopping centres in providing access to cooled environments during hot days and other extreme weather events.

Incorporating these considerations into residential and neighbourhood design through the planning process will improve resilience to climate change impacts over time, but more targeted intervention is needed to cool existing homes and residential areas which are already disproportionally exposed to heat risk.

Section 2: NSW case study research

This section reports on the case study component of the project, discussing methodological constraints and strategies and outlines key qualitative findings.

The three case study areas were as follows:



Methodology and scope

Given the scoping nature of this study, it was important to choose fieldwork sites that suggested as comprehensive a range of social, geographic and climactic contexts as were manageable within the available time and budget. The project focussed on inner-city Sydney and Sydney's far Western suburbs; and both coastal and inland regional areas of the state (inner and outer metropolitan, and inner and outer regional areas).

For the coastal case study, Chief Investigator Tess Lea and Research Associate Christen Cornell visited the Northern Rivers region, specifically Byron Bay and Lismore, which is forecast to experience increased heat and incidences of heavy precipitation (and thus more flooding, humidity, storms). For inland NSW, Lea and Cornell visited the drought-afflicted towns of Dubbo and Walgett, where predictions are for higher temperatures, and longer stretches without rain. These case studies thus cover both urban and rural, and hot and humid conditions.

Given the fact that the project's subject populations are, by definition, vulnerable – and potentially living in illegal housing – we chose not to approach householders directly. We did not want to risk exacerbating their precarity. Instead, we favoured speaking with community service providers and advocates, or those who are on the frontline of attending to housing vulnerability. In each fieldwork case study site, we spoke with people such as housing workers (including tenancy advocates and staff at migrant settlement services), community lawyers, academic researchers, demographers, campaign organisers, elected Councillors, local government staff, Aboriginal Elders, staff at Local Aboriginal Land Councils and/or staff at Aboriginal Medical Services.

Interviews were semi-structured and relatively informal, taking between 30-90 minutes. Over 20 people were interviewed, the majority face-to-face, while one interview was conducted over the phone.

The possibility of assisting the NSW Department of Planning, Industry and Environment's evaluation of its Home Energy Action program, which is designed to delivery energy efficiency improvements to households in need across NSW by providing subsidies for upgrades to community housing providers was initially canvassed with the project sponsors. However, as the project progressed, it became clear that evaluating the program and establishing people's fundamental concerns about housing, health and climate change, were not entirely compatible, and this approach was not pursued.

Everybody with whom we spoke in our fieldwork was keenly aware of the ways that socio-economic and health vulnerabilities are compounded by extreme weather events. They were aware of the links between housing, health and climate change; and extremely keen to discuss the issue and the public investments and infrastructure required to mitigate existing and increasing risk.

The drawings included in the following section are depictions of sample dwelling types that have been identified as increasing residents' vulnerability to extreme weather. These have

been included as a means of representing these housing conditions without impinging upon residents' privacy with photography.

Findings

NSW has an affordable housing crisis and this is a climate change issue

One of the most striking findings of our fieldwork is that questions of climate change adaptation in NSW cannot be addressed without first acknowledging that the state already faces a widespread housing crisis. Problems of housing affordability stretch far beyond central Sydney, purportedly easing only in the far West of the state; where they become replaced by problems of exposure to extreme heat and water insecurity. Once we overlay the stresses of climate change to already strained civic and regional infrastructures across the board, the nexus of housing, climate change and disadvantage becomes clear.

Examples of precarious, marginal and informal housing are now visible in places where one might least expect it, such as Byron Bay (otherwise famous for exemplifying "the good life") and rural Lismore. At last count, conducted by Byron Community Centre in 2018, Byron Bay had around 50% the number of rough sleepers as found in central Sydney.[6] Rough sleepers, or more formally, people experiencing primary homelessness, are defined by Chamberlain and Mackenzie as people living on the streets, sleeping in parks, squatting in derelict buildings or using cars or railway carriages for temporary shelter (Chamberlain and Mackenzie 2014), which is operationalised using the Census category 'improvised homes, tents and sleepers out'. In the Byron region, women in their 50s make up a growing demographic of people living in their cars, along with single mothers keen to keep their kids close to schools. Byron Bay also has a growing number of people living in unregulated dwellings on rural farms, such as tents, caravans, or agricultural structures.

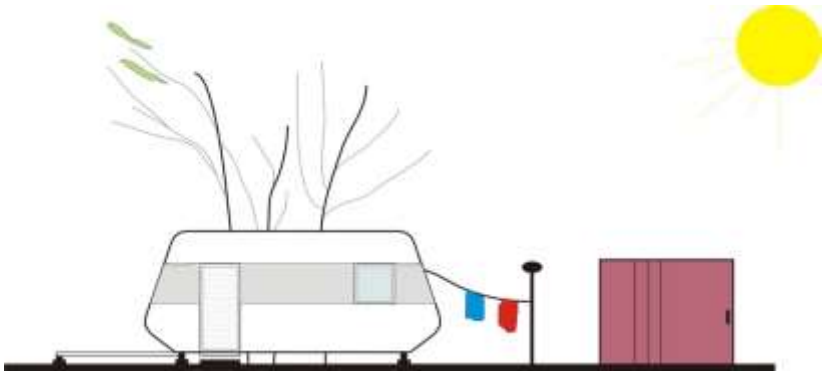


Figure 5: Caravan. Image by Pranita Shrestha

[6] This statistic was published by Byron Community Centre on their website following their 2018 street count. https://byroncentre.com.au/tag/rough-sleeper/ . In 2016, the Australian Bureau of Statistics census results suggested that Byron Bay has the second highest number of rough sleepers in NSW outside central Sydney.

We were told one story of several families sharing a converted mushroom shed on a property in the humid Byron Bay hinterlands, with hospital blankets used as room dividers. In Lismore, we learnt that a lack of affordable housing has led to people building in the spaces beneath the stilts of their old 'Queenslanders' and renting or subletting these informally to people with few other housing options. Homelessness, overcrowding and unhealthy living conditions are therefore not only an urban problem, but are taking shape in deceptively wealthy or plentiful rural social landscapes as well.

In Sydney, precarious and informal housing is a growing problem, particularly in the outer suburbs. In the hot (and cold) Western suburbs, granny flats are being adapted for multi-occupancy rentals, and people are renting verandas on which to sleep while struggling to get into the official private rental market. To avoid the price of regulation, such housing does not declare itself, with the result that it is under-reported and under-researched.

Whether in Sydney or regional parts of NSW, the housing that is most available to those lacking in social or economic resources is also the housing that is most unhealthy, or unsafe, in extreme weather conditions. In the Sydney case study, interviewees advised that cheaper housing is typically old housing stock in the Western suburbs – without air conditioning or insulation, hot in summer, freezing in winter. Higher floor apartments perform relatively well in winter, but as one housing worker we interviewed commented: 'in summer people are just cooking'.

Newer apartments with air conditioning or which are explicitly designed for non mechanical thermal comfort are rarely affordable or available for lower income rental in the private market. Energy costs associated with air conditioning burden lower income tenants disproportionately, and this 'energy stress' is projected to intensify in the future. In conditions of climate-induced state emergency – such as extreme heat events, power may be reduced or unreliable.

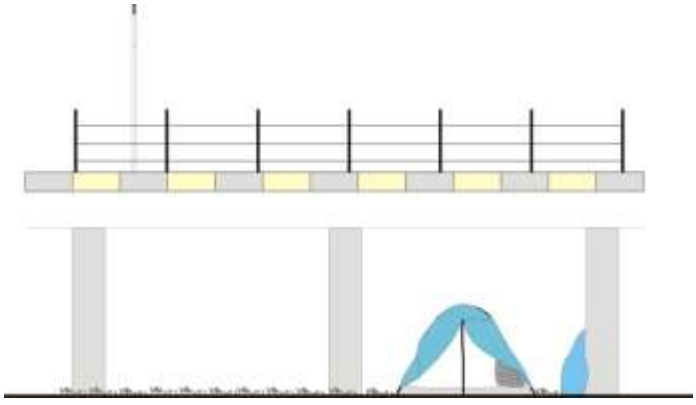


Figure 6: Tent. Image by Pranita Shrestha.

In the Northern Rivers region, low cost housing is typically in flood affected areas, and so are the first sites to be inundated during extreme storms and flood events. Similarly, other forms of low cost accommodation such as caravan or mobile home parks are often situated

in floodplains and or particularly vulnerable to storms and cyclones. Despite their name, permanently occupied caravans and mobile homes are often difficult to move without damage and many have very poor thermal performance. Of course those sleeping rough or in cars are entirely exposed to extreme weather, and interviewees expressed concern about the health of itinerant bush and van campers in the Northern Rivers.

Heat is a frightening issue for communities in Walgett where temperatures can reach 50 degrees, and lack of water is already at a critical – even permanently exhausted – point. In Walgett, the shortage of affordable rental accommodation puts pressure on kinsfolk to accept more families into a house. The health risks associated with high temperatures and inadequate accommodation are compounded by overcrowding.

Figure 7: Elevated house with built-in dwelling beneath. Image by Pranita Shrestha.

Market responses to risk

A related question is that of insurance, and of who is to be left with the problem of risk in the context of climate change. To date, those with the least exposure to risk are able to access lower cost premiums, while many who are living in housing that is vulnerable to climate-related risks – such as sea level rise, increased floods or bushfire zones – may be unable to access or afford insurance. (This may alter as climate changes impact formerly advantaged regions or where the costs of risk are spread). Further, those living in rental or marginal accommodation are much less likely to access insurance for their belongings. Overall, rental tenants are more likely to be displaced if their home is damaged during an extreme weather event, forced to relocate when landlords undertake, repairs, reconstruction, or elect not to rebuild at all.

In Walgett, Aboriginal housing service providers advised that they are under pressure to charge rents that enable insurance and maintenance cost recovery. This compounds affordability issues, limiting the stock that can be made available.

Discussing the future of Aboriginal communities in remote parts of NSW, one Dubbo participant predicted an eventual total withdrawal of government services from all small to

medium sized communities. For him, this prediction was based on increasingly privatised delivery and administration of government housing which appears to be exacerbating rather than improving problems in service delivery and essential property maintenance. While exploring issues of viability was not a focus for this report, we anticipate the concerns expressed here will increase as climate change continues to alter water security and weather conditions.

Figure 8: Overcrowding in high-rise apartments. Image by Pranita Shrestha.

Better communication and regulation

As we have noted in Section one, lower cost housing is often the most expensive to power, being old, badly sited, and/or poorly designed, and so those with the least financial resources are often paying the most in energy costs, thereby sliding into further financial stress. Our interviews have elicited stories of people (the elderly in particular) suffering dangerously hot or cold conditions to avoid inflated energy bills. Others have told of families that are already in debt receiving unrealistically high power bills, putting them at risk of disconnection.

There are a range of subsidies and schemes designed to assist consumers in their efforts to reduce energy costs, such as off-peak pricing, or the NSW Government's Home Energy Action Plan. The latter however is only available to Community Housing Providers, and others (such as the Aboriginal Medical Service, or those working for tenants in state-managed public housing) expressed a desire to have this scheme expanded and made more widely. Even more significantly, perhaps, systems such as on-peak off-peak pricing are not comprehensible to many vulnerable people and communities, since they require particular linguistic competencies that are often not held by those living in social or low cost housing. As systems designed to reduce energy costs, these schemes can fail to reach those upon whom they may have the greatest impact.

For recently arrived migrants in Sydney's outer suburbs, and for the Aboriginal communities of the Northwest, there is a clear need for more culturally appropriate communication of energy saving schemes for such schemes to be successfully implemented. This communication may involve visits to people's homes (an idea suggested by a CEO of a Local Aboriginal Land Council), or it may involve contracting community groups or workers as cultural liaisons (suggested by organisers in the Sydney Alliance's Voices for Power campaign).

Figure 9: Rough sleeping. Image by Pranita Shrestha.

Local Government is playing an important role

Interviews with local government workers, planners and compliance officers have suggested that local government is currently playing a key role in responding to the everyday needs of people living in precarious housing conditions through their community service functions. This is often without the revenue associated with enumerated residents (through property rates), and in isolation to the wider Commonwealth/state housing assistance programs.

However, local council staff and compliance workers are often at the coal face of homelessness and inappropriate housing conditions. When they encounter people living in unauthorised, improvised or unsafe dwellings, they are confronted by the lack of alternative housing available to refer to people to. As one employee from Byron Bay Council remarked of residents living in high risk informal dwellings: 'There's nowhere for them to go.'

Summary of findings from NSW Case Study research

Together these findings demonstrate that insecure, unaffordable or marginal housing significantly exacerbates residents' vulnerability to climate change. Moreover, growing numbers of lower income individuals and households are likely to experience increased risk of climate/housing related vulnerability unless affordability pressures are addressed.

Vulnerability to extreme weather events is exacerbated by:

- dwelling structure (e.g. poor thermal performance, under-engineered for new threats);
- tenure (e.g. those living in boarding houses, social housing, or renting in the private market have limited ability to adapt their dwellings, a limited ability to persuade landlords to make modifications; and are be more vulnerable to displacement if their homes are damaged by a natural hazard such as flood, storm, or fire);
- dwelling location (lower cost housing is often located on land that is more vulnerable to extreme weather events or which is less accessible to services and transport);
- social isolation, lack of connectedness, or unfamiliarity with the local area and emergency protocols / responses; and
- underlying health conditions of individuals, including predisposing risk factors such as age and or disability.

Lower cost rental housing is often the most expensive to power (due to the age, building materials, and condition of the dwelling), and so those with the least financial resources are often paying the most in energy costs, and thus sliding into further financial stress.

Tenants in both the private rental and social housing sectors are severely limited in their ability to adapt their dwellings to increasing heat or other extreme weather events.

These conditions, as well as potential mitigation techniques, are depicted in the housing typology presented in the following section, along with a map of potential 'hot spots' of vulnerability in NSW.

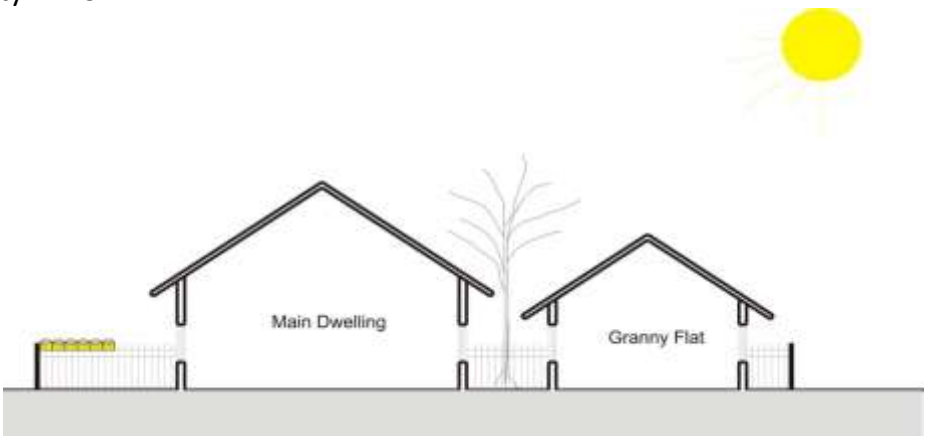


Figure 10: Granny flats adapted for multiple occupancy. Image by Pranita Shrestha.

Section 3: Housing typology and 'hot spots' of potential risk

This section combines existing international knowledge about the intersections of housing, health and climate risk (presented in Section One) and synthesises it with interview-generated data collected in the NSW case study research (presented in Section Two) to produce:

1. A housing typology that identifies particular health and climate risks associated with specific dwelling types occupied by high need groups in low cost social, private, rental and marginal forms of housing tenure; and
2. Maps of hotspots of potential climate vulnerability in NSW, and our three case study regions.

It should be noted that our maps were collated using existing government data, and have not been revised since the devastating fires of summer 2019/2020.

Typologies of housing and residential neighbourhoods which are relevant to assessing heat and other climate-related health risks.

Drawing on the wider research on housing need, the following categories are relevant to understanding housing related vulnerability to heat and other climate-related health risk:

Characteristics of the household: household size; composition and type (group or extended family); ages of household members and their health conditions.

Tenure: whether or not the household lives in their own home (owned outright or being purchased); is renting a dwelling in the private sector, public or community (social housing) sector, or is in marginal / non-standard accommodation (for example crisis housing, boarding houses, caravan parks / manufactured home estates). Tenure defines the extent to which the household is able to undertake modifications to their home, as well as their capacity to choose how long they can continue to occupy the dwelling.

Outright owner occupation offers the most secure form of tenure, and the greatest capacity for households to modify their home for improved thermal performance and climate resilience; certain types of accommodation in the private rental sector, such as boarding houses, or informal agreements without a written contract, offer the least.

Characteristics of the dwelling: the dwelling type (detached house; attached villa/townhouse; apartment; other, non-standard dwelling including a non-residential building or an illegal dwelling); size (relative to household size and composition); age and condition; design and orientation (for solar access/shade; ventilation; thermal performance); materials and appliances (thermal performance,

energy efficiency); adaptability (capacity for retrofitting to improve thermal performance / climate resilience).

Characteristics of the neighbourhood and location, including climatic zone: overall housing density and built form (high, medium or low density housing; solar access / shade; breezes; tree canopy and vegetation; impervious surfaces / urban heat island effects); neighbourhood / community facilities (libraries, shopping centres, health facilities, public open space); accessibility / mobility / car dependency; climatic zone (and projected weather / heat patterns in short and medium term).

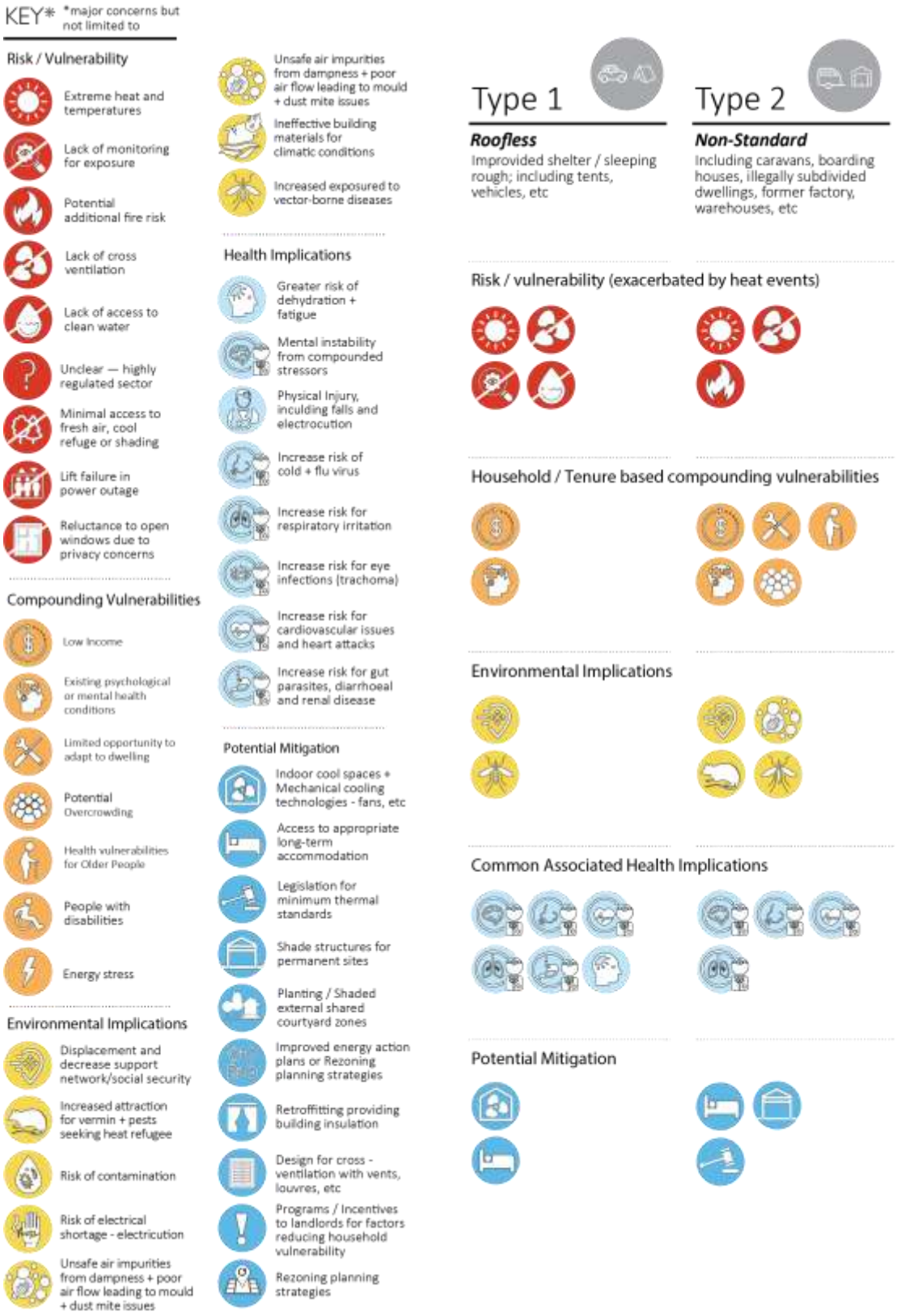
Using these categories, and incorporating the findings presented in the previous section, we have created a typology of housing related to climate risks to human health. This typology is presented in two different formats: first in a table, arranged on a spectrum of inland to regional scenarios; second with use of infographics, visualising this same information.

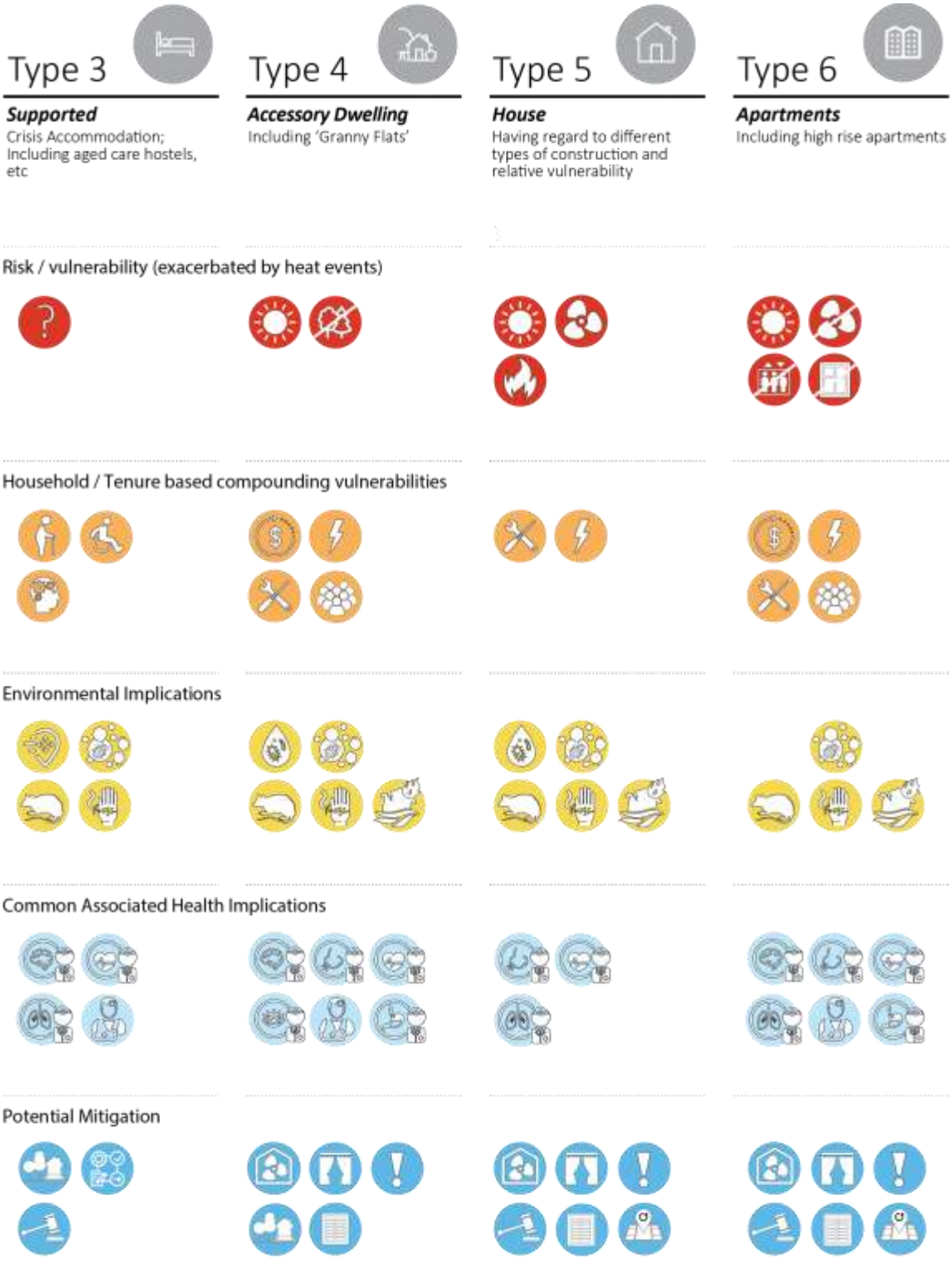
Typology of housing related to climate health risk – Table form

Geographical Zones	Climate Factors	Environmental Attributes	Exacerbated Risks	Compounding Vulnerabilities	Housing / Tenure Factors	Environmental Implications	Health implications
Inland	Increased heat	Drought	Water supply/efficiency Displacement Subfloor ventilation Distance to public transport and the beach	<4 and >65	Hygiene Hydration Overcrowding Pests	Disease Infection Overheating + dehydration	Cardiovascular Heart attack Trachoma Diarrhoeal disease Scabies + other skin infections
		Bushfires	Isolation; limited evacuation routes Displacement	Unattended slow mobile persons Uninsured	New tenants unfamiliar with area or fire risks	Support network - social security	Mental illness: Isolation + Loneliness Injury, respiratory problems/ high heat exposure
		Sun Exposure	Trapped heat from poor ventilation and insulation Energy Demand Animals, insects and vermin seeking heat refuge Distance to public transport and the beach	<4 and >65 Low Income	Hydration Overcrowding	Heat Island Overheating, dehydration + Fatigue + confusion	Physical injuries from falling Heat induced comas Heat eczema, rashes, cramps, exhaustion, syncope, hyperthermia, seizures

	Dust Storms	Disrupted ecosystem	Air Quality Animals, insects and vermin seeking heat refuge	<4 and >65	Air flow Electrical cable and water pipes attacked	Dust mites Electrocution Water shortage	Respiratory issues
	Colder temperatures		Thermal performance – poor insulation and building materials Energy Demand	<4 and >65 Low Income	Heat escape	Spread of viruses	Viral Infections Respiratory issues Pneumonia Body Temperature and blood flow – Hypothermia + heat problems
	Increased Precipitation	Flooding	Displacement Population density Structurally unprepared Waste removal / drainage	Uninsured Low income	Overcrowding Population density Lack of resources Mould and pests Electrical shortage Contamination	Support network - social security Disease + Infection Eye health Electrocution Poor nutrition	Mental illness: Isolation + Loneliness Respiratory issues Trachoma Injury from fire or structural collapse Renal disease Mosquito borne illnesses Gut parasites
Coastal	Hurricanes Cyclones	Structural damage	Displacement	Uninsured	Overcrowding Population density Lack of resources	Support network - social security	Injury from structural collapse Mental illness: Isolation + Loneliness

Typology of housing related to climate health risk – Infographics





HOUSING TYPOLOGIES

Housing related climatic risks to human health

Mapping of 'hot spots' of vulnerability in NSW

The following maps draw on NARCLiM data for NSW, and the three case study regions, to map hotspots of vulnerability to climate change in the relevant areas. Overlaying projected heat maps with those for significant changes in precipitation, these suggest areas of particular risk in the near future, while integrating our interview-generated data concerning housing scenarios and their locations.

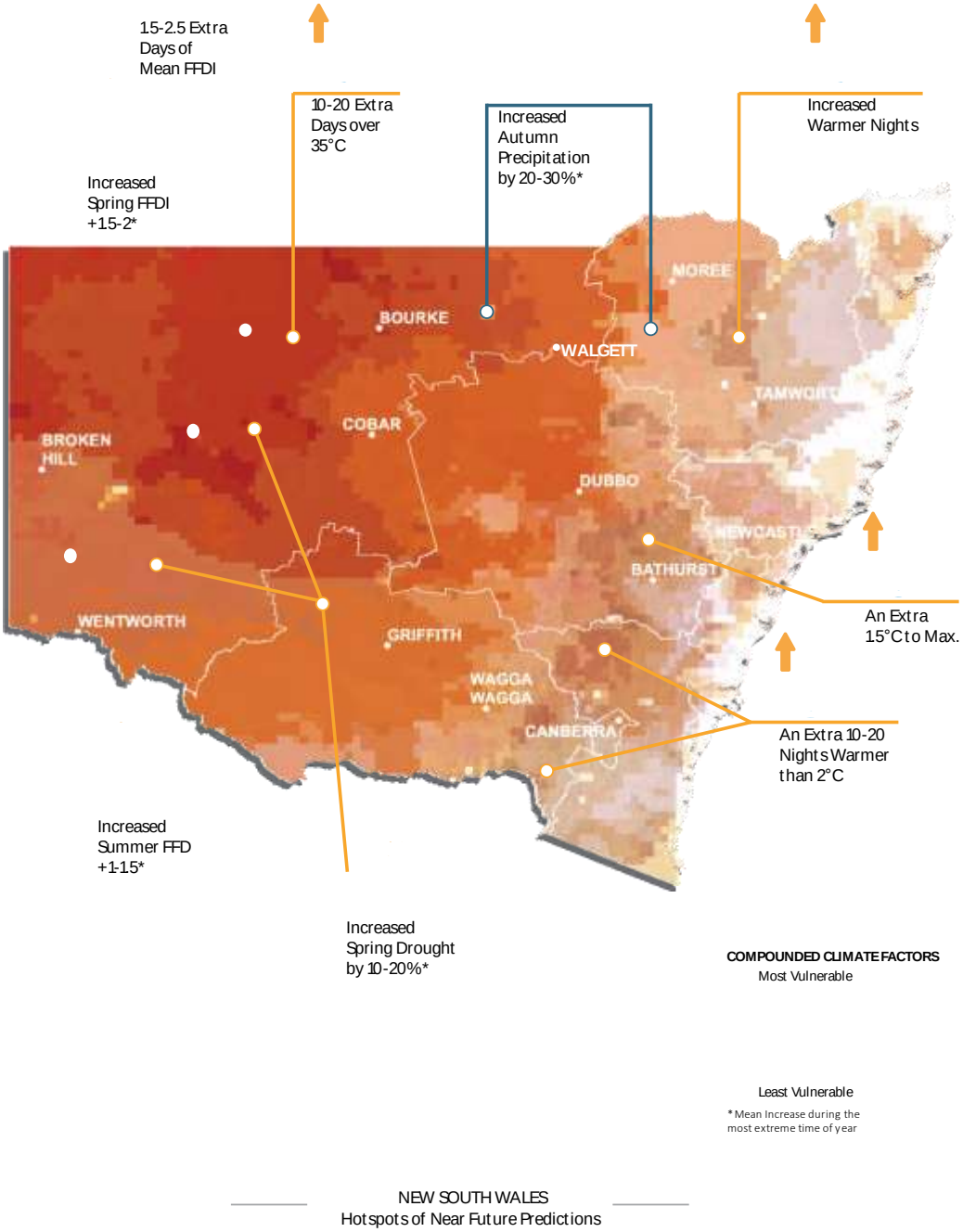


Figure 11: Hotspots of climate vulnerability: NSW
Source: the authors, building on NARCLiM data.

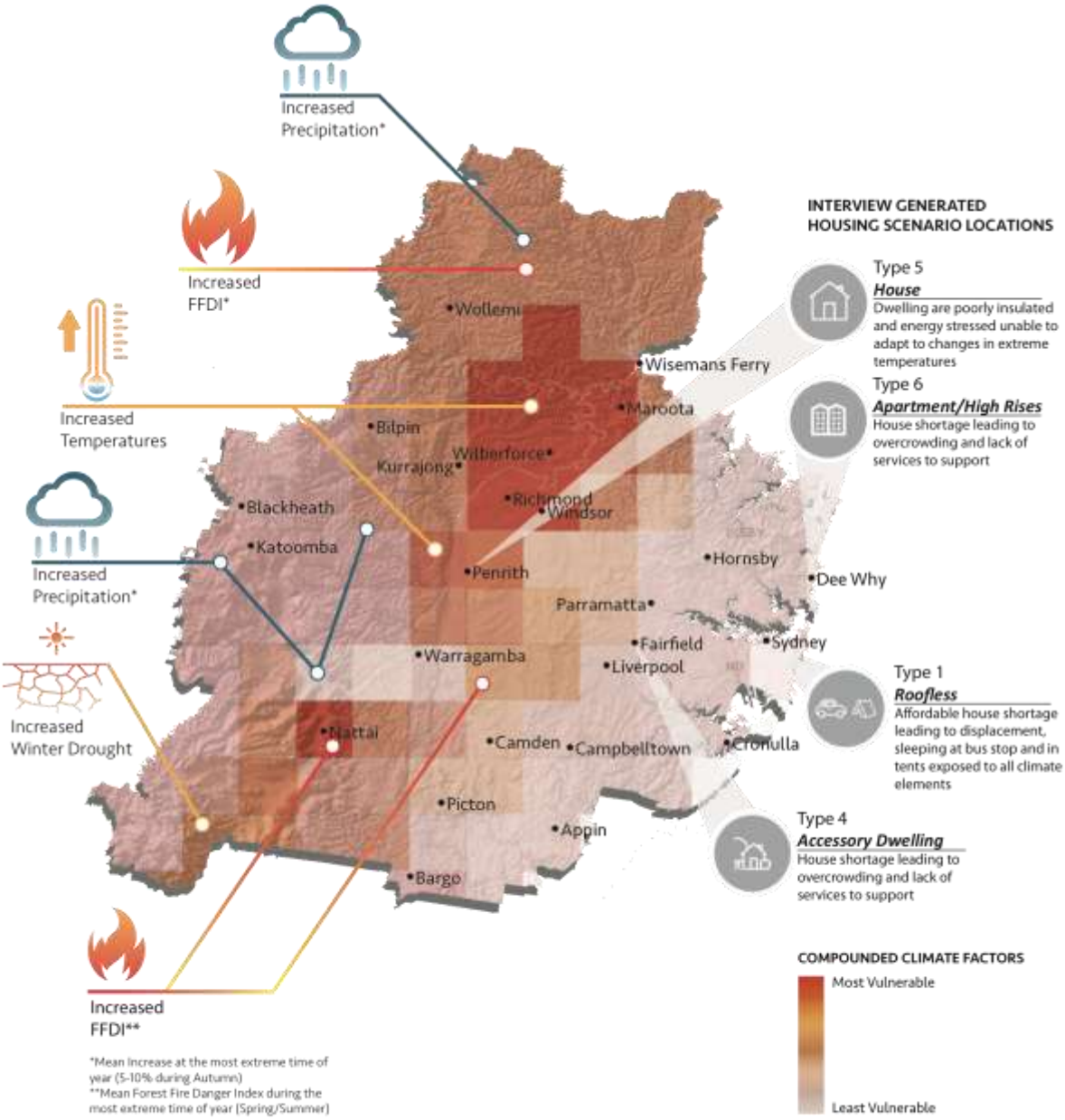


Figure 12: Hotspots of climate and housing vulnerability: Sydney
Source: the authors, building on NARCLiM data.

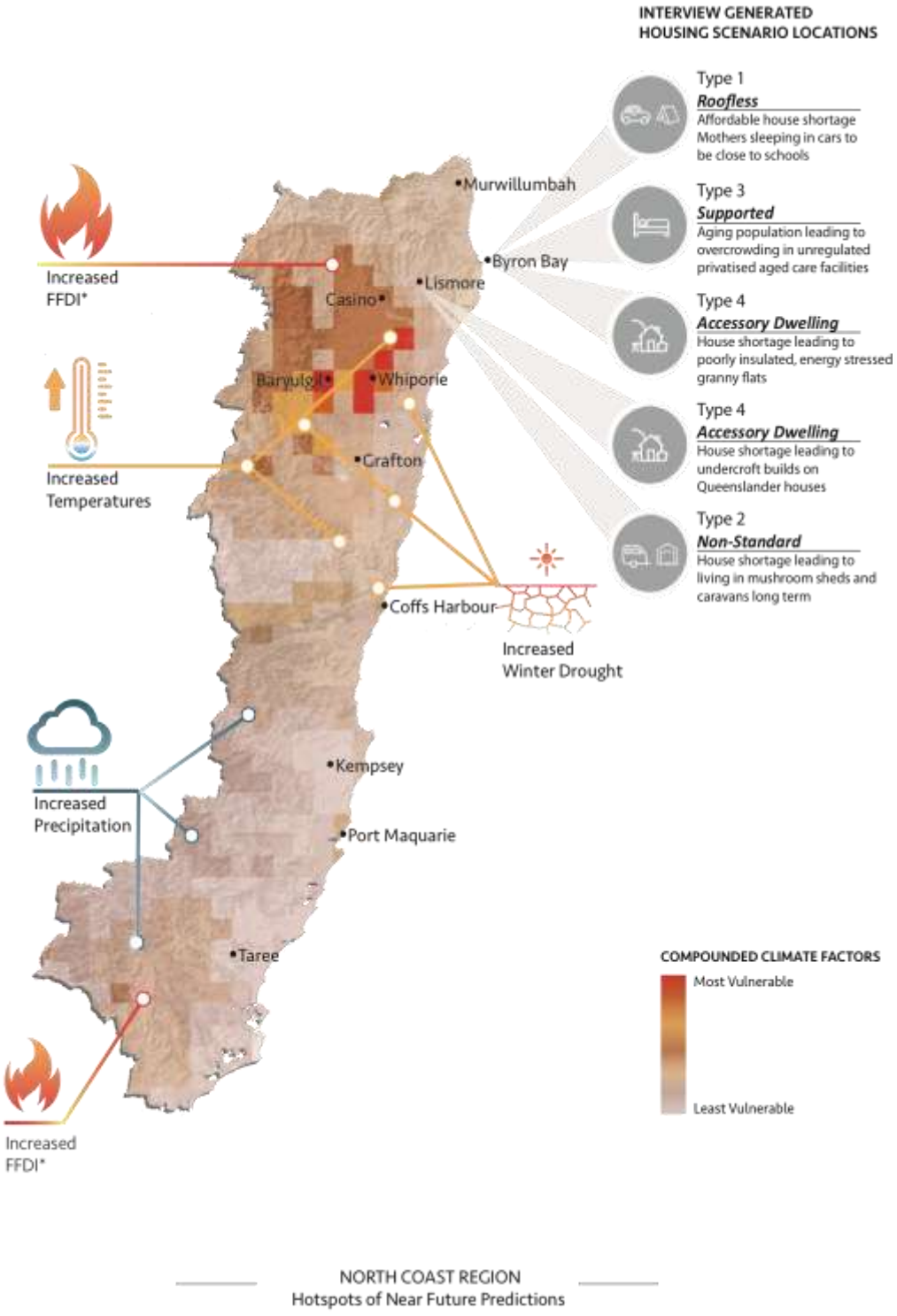


Figure 13: Hotspots of climate and housing vulnerability: Northern NSW
Source: the authors, building on NARCLiM data.

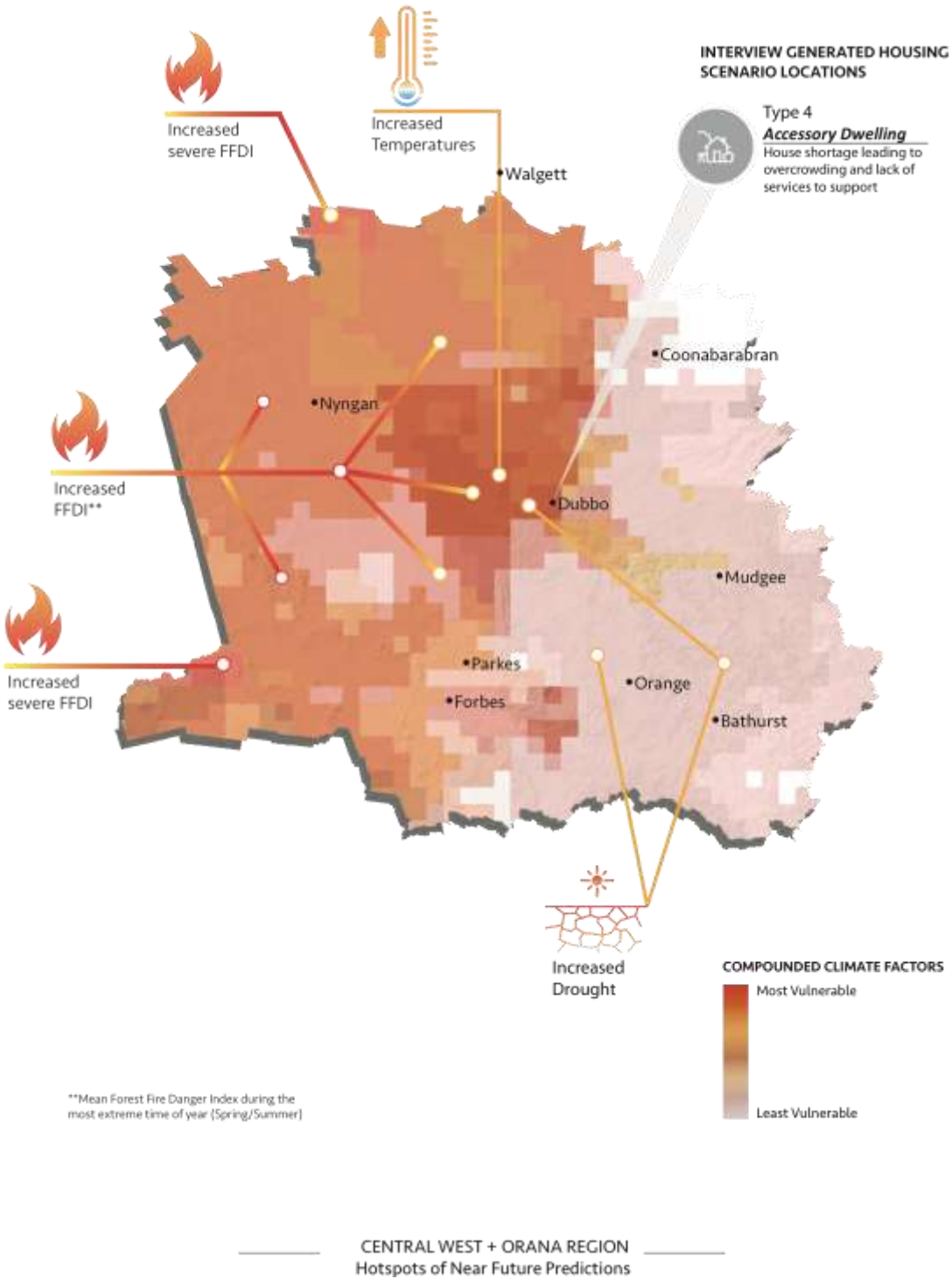


Figure 14: Hotspots of climate and housing vulnerability: Northwest NSW
Source: the authors, building on NARCLiM data.

Section 4: Priorities for research and policy development

This project has identified numerous issues relevant to understanding the intersections between climate change, housing and health. It finds that those who are the most vulnerable to the risks of climate change, also have the least capacity to adapt their housing to better withstand these risks, including risks arising from high heat which were a particular focus for this study. People who are sleeping rough and at risk of homelessness; living in informal and inadequate housing; residents of supported accommodation; low income private renters; and in some cases social housing tenants and lower income home owners, all face potential barriers to effective climate adaptation.

In this section of the report we highlight the priorities for research and policy development, in responding to these issues. They include:

- The need for more detailed vulnerability mapping to identify overlapping clusters of risk to housing and health related climate change impacts (housing tenures, building types, demographic profiles, and climate risk geographies);
- The development of transitional strategies to improve awareness about these risks and potential short term heat risk mitigation strategies through more targeted public health information for individuals with particular housing needs and their care givers, housing providers, and community service agencies;
- The development of more fundamental changes to the built environment which reduce exposure to climate change impacts on health overall and heat risks in particular through improved design of new development and retrofitting of existing communities;
- The introduction of new and enhanced programs to improve the climate adaptation capacity of housing stock in the private rental sector, in particular, thermal performance; potentially through landlord loans/grants made contingent on agreements around rental tenure and rent security; and the introduction of specific strategies to address heat and other climate-related risks faced by residents of non-standard and informal housing (e.g. caravan parks / manufactured home estates).
- A reassessment of existing and potential strategies and resources available to providers of services for the homeless and of crisis accommodation, to provide additional, targeted assistance to vulnerable populations during extreme weather events.

An important insight of this project has been an identification of the *lack* of policy frameworks and discussions regarding how these issues of housing, health and climate change are intimately connected. Rather than simply prescribing what policy should do, therefore, we emphasise the need to recognise issue interconnectedness, and to commence discussion across different community and stakeholder groups, so that the coordination that will be increasingly required (between agencies, organisations, communities) can begin. In particular, public education and consultation rounds about where people should and can live as climate change deepens its impact should commence now.

The New South Wales Government's existing Climate Change Policy Framework[7] provides a starting point. It indicates a commitment to direct interventions with incentives to encourage industry investment in climate mitigation and emissions reduction targets. It does not mention housing at all, but suggests the need to embed climate change considerations into asset and risk management strategies, which, by extension would include housing and urban infrastructure. However, as highlighted in this scoping study, housing and neighbourhood infrastructure are more than physical assets – playing a vital role in community wellbeing, health, and resilience. Further, physical adaptation strategies alone are not sufficient to address the complex housing and health related climate vulnerabilities outlined in this study.

Vulnerability mapping

There is a need to further bring geospatial data on particular climate risks, including heat and humidity, together with data on housing need and deprivation; and geographies of known demographic / health characteristics. This could occur through regional planning processes, coordinated by the NSW Government.

NARCliM data is provided via the climate portal at Adapt NSW, and provides an important resource in this regard. The Socio-Economic Indexes for Areas (SEIFA), produced by the Australia Bureau of Statistics could also assist as a value of vulnerability especially relating to social disadvantage. These can be prioritised for health and housing interventions.

Linking with other research groups, such as the Global Water Institute at the University of New South Wales, and the University of Tasmania's Fire Centre Research hub, together with health, housing, planning and engineering expertise at the University of Sydney, would help ensure some of the connections necessary for forward policy.

Service planning and communication

Local government and community sector organisations need resources and training to properly include hotter norms and heatwaves in their planning and service delivery. Strategies for monitoring at-risk groups – particularly people who are homeless, living in social or affordable housing, and in boarding houses – are needed. Special communication with aged care and supported accommodation sectors may also be required.

There is a need to evaluate the efficacy of existing local strategies for publicising the availability of public facilities offering air-conditioned respite, and helping vulnerable populations to access these facilities.

[7] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-climate-change-policy-framework-160618.pdf

While information on how to adapt to climate risk can be helpful, information campaigns are likely to fail if divorced from people's daily practices, infrastructural capacities and cultural norms. An important finding from the fieldwork is that many vulnerable groups are unaware of, or unable to access, appropriate housing or energy saving programs due to their relative isolation from government messaging, their lack of English skills, or their understandable preoccupation with more immediately pressing issues that often characterise lives circumscribed by social, economic and health vulnerability.

For this reason, there is a need to work collaboratively to generate local solutions with vulnerable communities, and to adopt culturally specific communication methods (potentially through cultural liaisons) to be more effective in assisting householder adaptation. This includes the need for bespoke information to communicate with and protect Indigenous households, particularly in regional and remote areas. Such information must be specifically tailored for and co-designed with high-risk groups to have a chance at success.

Urban and residential design

Improving the thermal performance of new and legacy neighbourhoods and housing is a priority in NSW. The planning system integrates minimum requirements for solar orientation, insulation, shade, and landscaping into design and building requirements (for instance under the BASIX scheme (Gurran, Hamin et al. 2011). These requirements are also applied to housing alterations and additions. In this report, we have outlined important directions for improving performance in urban and housing design, building on these baseline standards to offset urban heat islands, reduce energy and car use, and shift to renewable energy systems.

However, new housing accounts for only 2% or less of the total housing stock in Australia, while it is only more affluent home owners and those able to live in higher quality rental housing who will benefit from improved thermal performance and energy efficiencies through home renovations. Many of the inadequate housing types identified in this report occur beyond the formal planning and development system.

Strategies to fund and implement improvements to the thermal efficiency and water harvesting capabilities of housing occupied by people most vulnerable to heat impacts should be prioritised, improving the quality, thermal efficiency, and cooling of low cost housing. Wider public realm strategies to reduce urban heat, and provide access to cool spaces, shading, water, and services in all communities should also be developed. Domestic water-capture and soakage schemes to prevent hard surface water run-off and loss in built environments, are also required on a mass basis. Ideally, noting the points above about success factors, such initiatives should include greater consideration of how to improve residents' varied capacities to participate within such initiatives.

Resilience retrofitting strategies

Social housing providers including Housing NSW have undertaken significant programs designed to improve the thermal performance of their housing stock and or to supply mitigation technologies, such as air conditioning units, to vulnerable tenants. The extent to which such programs may provide a basis for wider extension across the social housing portfolio and potentially the low cost private rental sector as well, should be examined, building on the work of Barnett et al. (2013, pp. 14, 15, 19). This may need to be off-set by considerations of how air-conditioning also can add environmental heat and tap power systems at times when energy requirements for emergency responses are also at their peak.

One possibility would be the introduction of low interest loans and or grants for landlords for the purpose of thermal installation or other energy efficiency / climate resilience modifications to rental properties. These programs would be offered subject to binding agreements around rental tenure and rent security for existing or targeted low/moderate income tenants, and a monitoring of compliance introduced.

A further avenue for retrofitting would target heat and other climate-related risks faced by residents of non-standard and informal housing (e.g. caravan parks / manufactured home estates). Again, low interest loan and or grant schemes could focus on local infrastructure or facilities designed to improve the resilience of these communities to extreme weather – in particular, high heat and humidity events.

Secure and affordable housing as a climate mitigation and adaptation strategy

Adaptation strategies targeted to the specific risks associated with particular housing vulnerabilities are a priority. For instance, many of the current strategies for responding to heat waves include preparations to make homes and apartments cooler, and imply basic facilities (fridges, air conditioners or fans); access to clean running water; or the capacity to install shades. These strategies are not feasible for many vulnerable populations living in insecure, illegal, or substandard housing. Expanding access to secure and affordable accommodation is the most appropriate adaptation response to these circumstances.

All levels of government can contribute to the increased provision of secure and affordable housing designed to mitigate climate change while also protecting residents from impacts already underway. Commonwealth and state governments will need to target housing budgets (including tax incentives for rental housing) towards expanding the social housing sector and to support affordable new low cost home ownership and private rental developments which also exhibit high environmental performance. States will need further action to reform of private rental laws, improving tenure security, alongside better regulating standards for dwelling quality and condition in the private rental sector. Local governments can encourage and facilitate high quality affordable housing developments through their planning and community development functions, in addition to making council land available for local affordable housing projects.

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Appendix: Scenarios depicting concerning housing types and climate-related health risks in NSW

The following scenarios build on the connections drawn in the housing typology, and NARCLiM weather projections, to illustrate specific housing types and associated health risks.

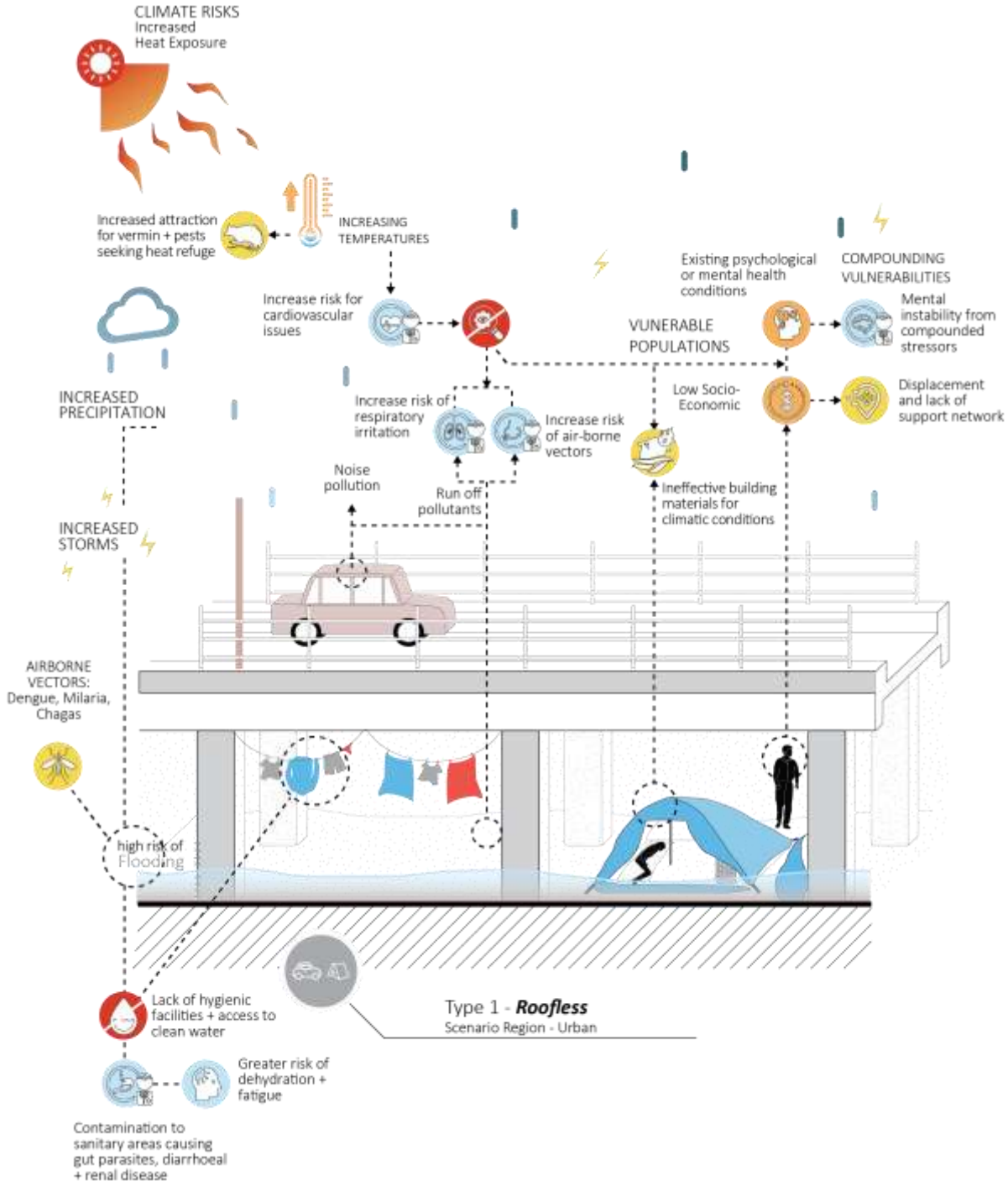

Figure 15: Climate-related health risks of Rooflessness (Type 1)
Source: the authors, building on NARCLiM data.

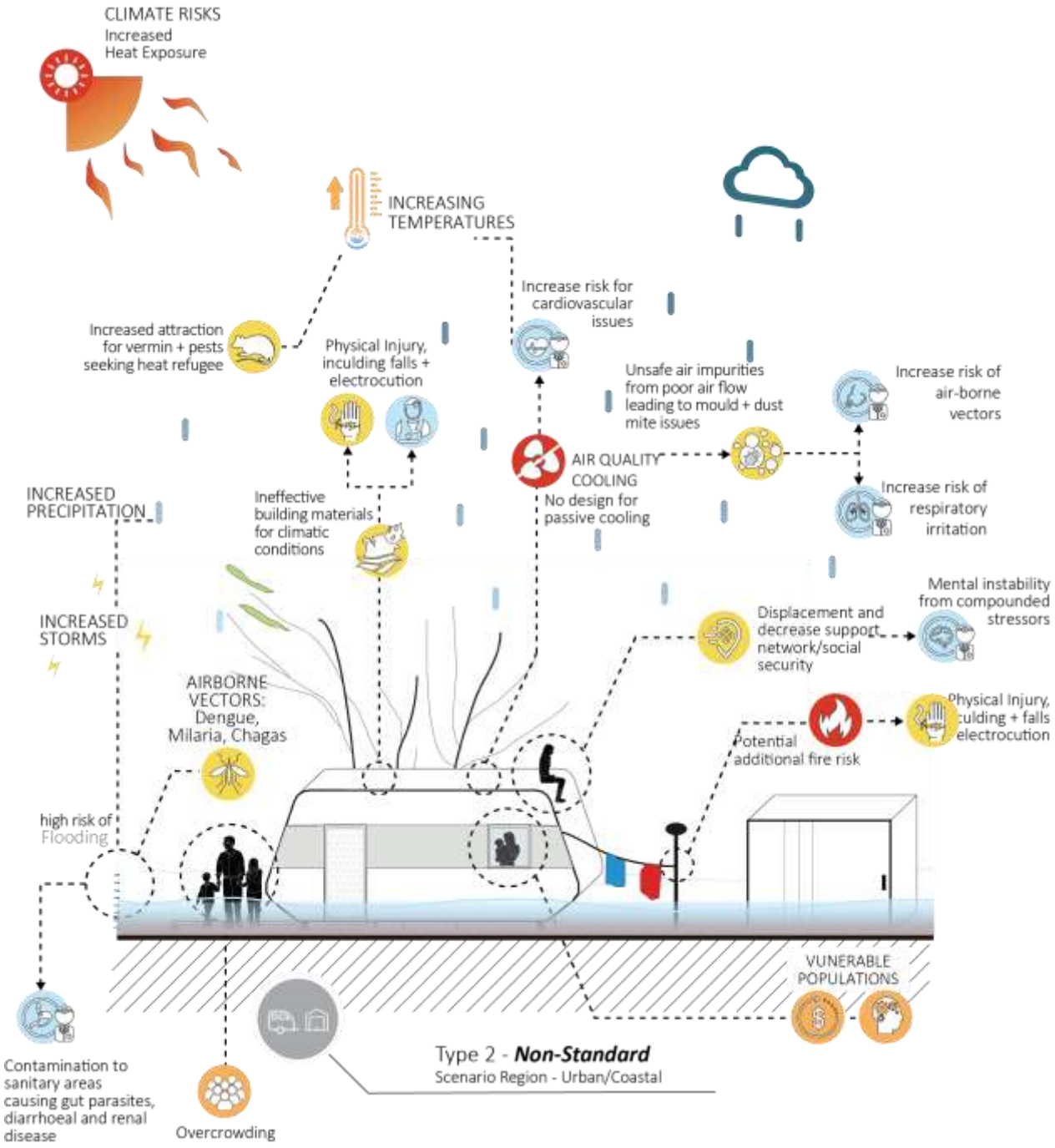

Figure 16: Climate-related health risks of Caravans / Non-standard housing (Type 2)
Source: the authors, building on NARCLiM data.

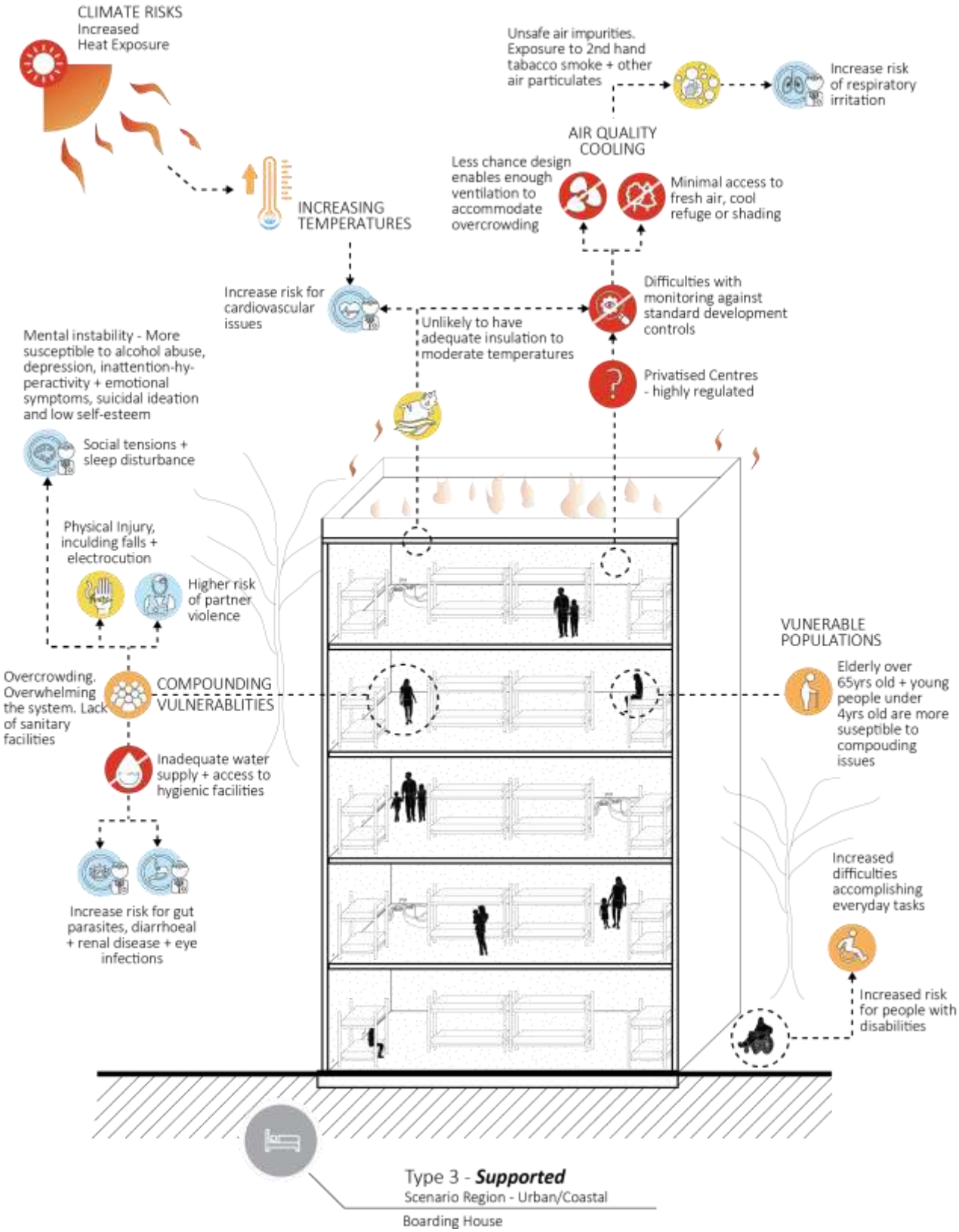

Figure 17: Climate-related health risks of Supported Accommodation (Type 3)
Source: the authors, building on NARCLiM data.

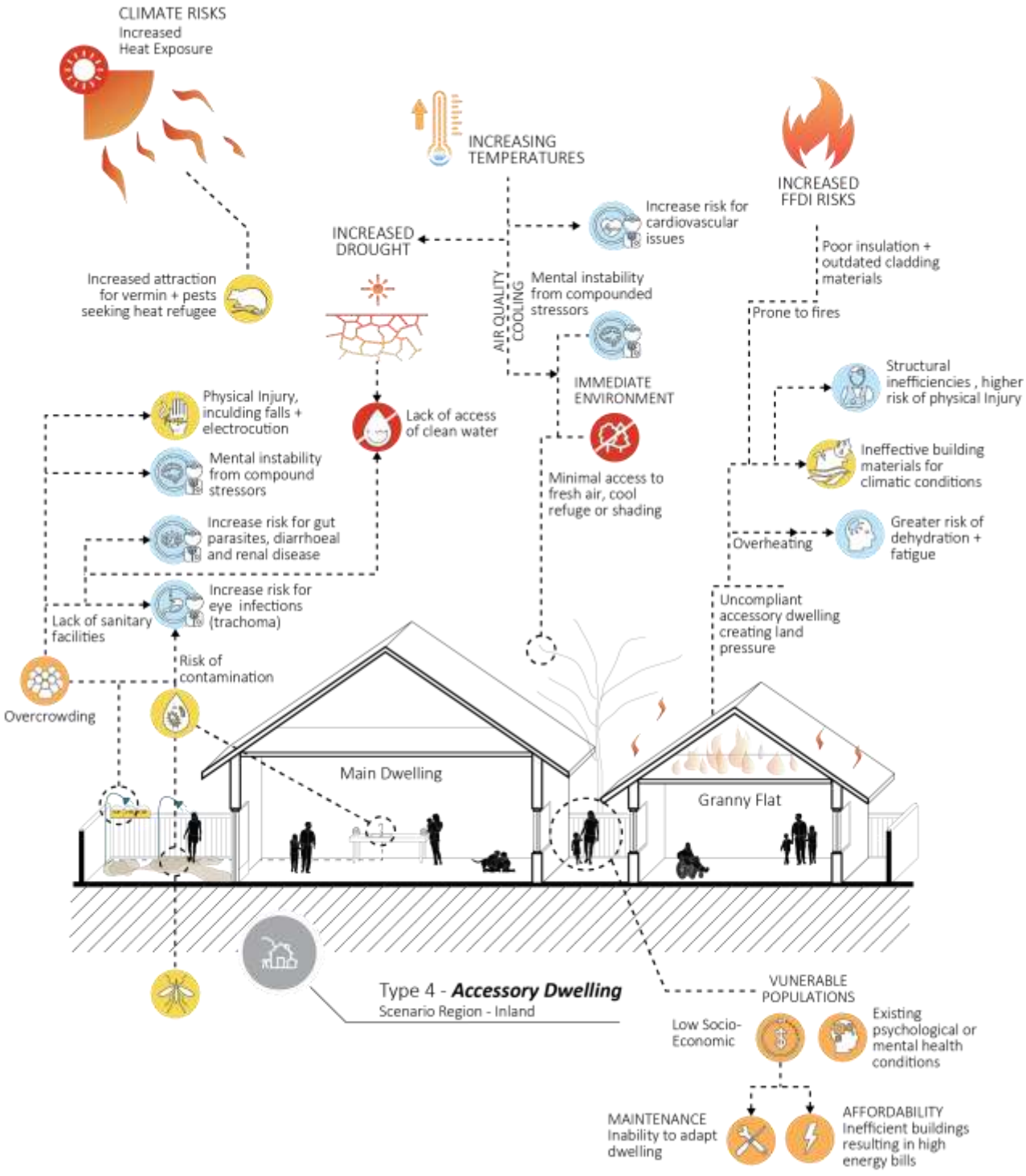

Figure 18: Climate-related health risks of Accessory Dwelling (Type 4)
Source: the authors, building on NARCLiM data

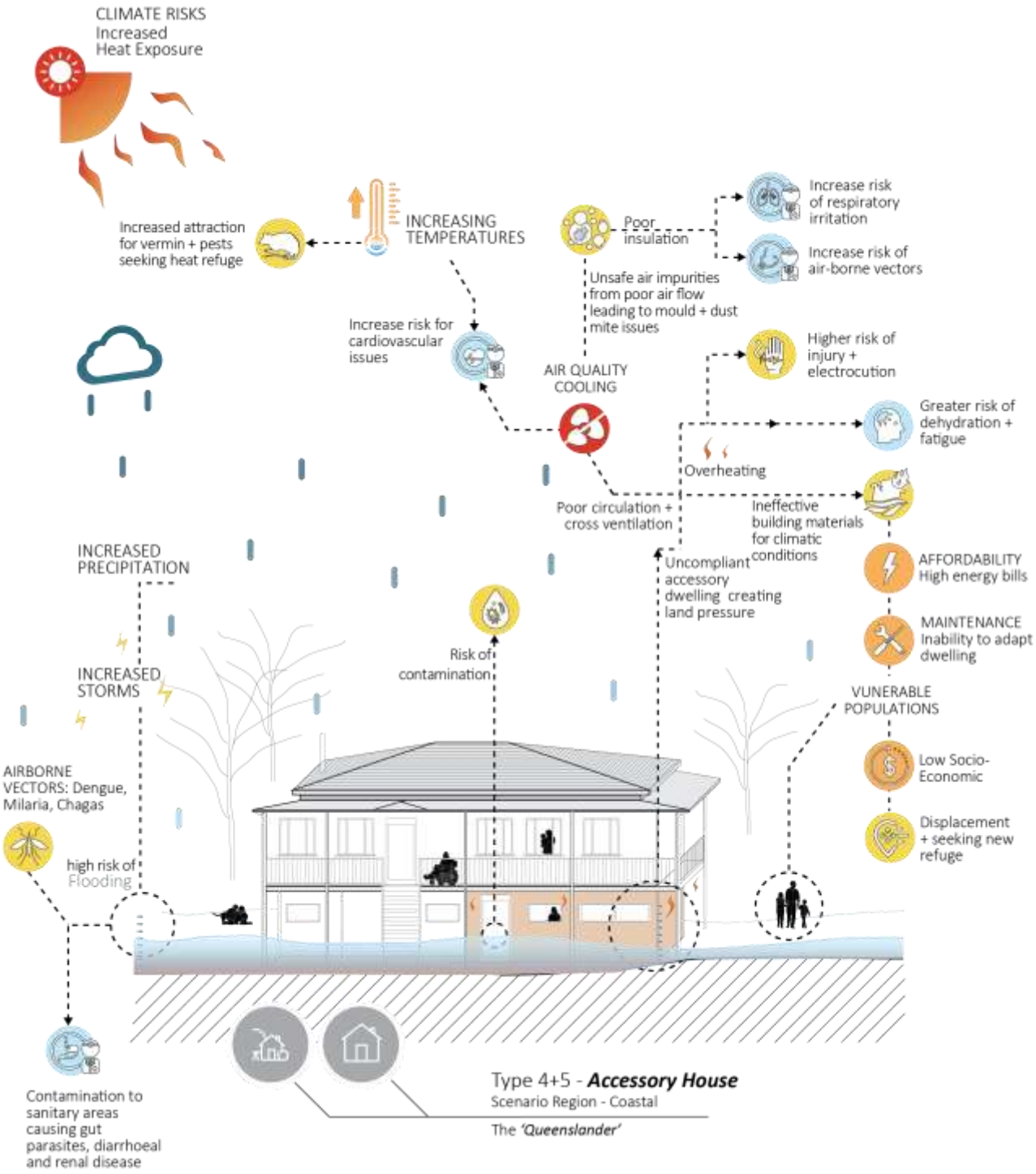

Figure 19: Climate-related health risks of House (Type 5)
Source: the authors, building on NARCLiM data

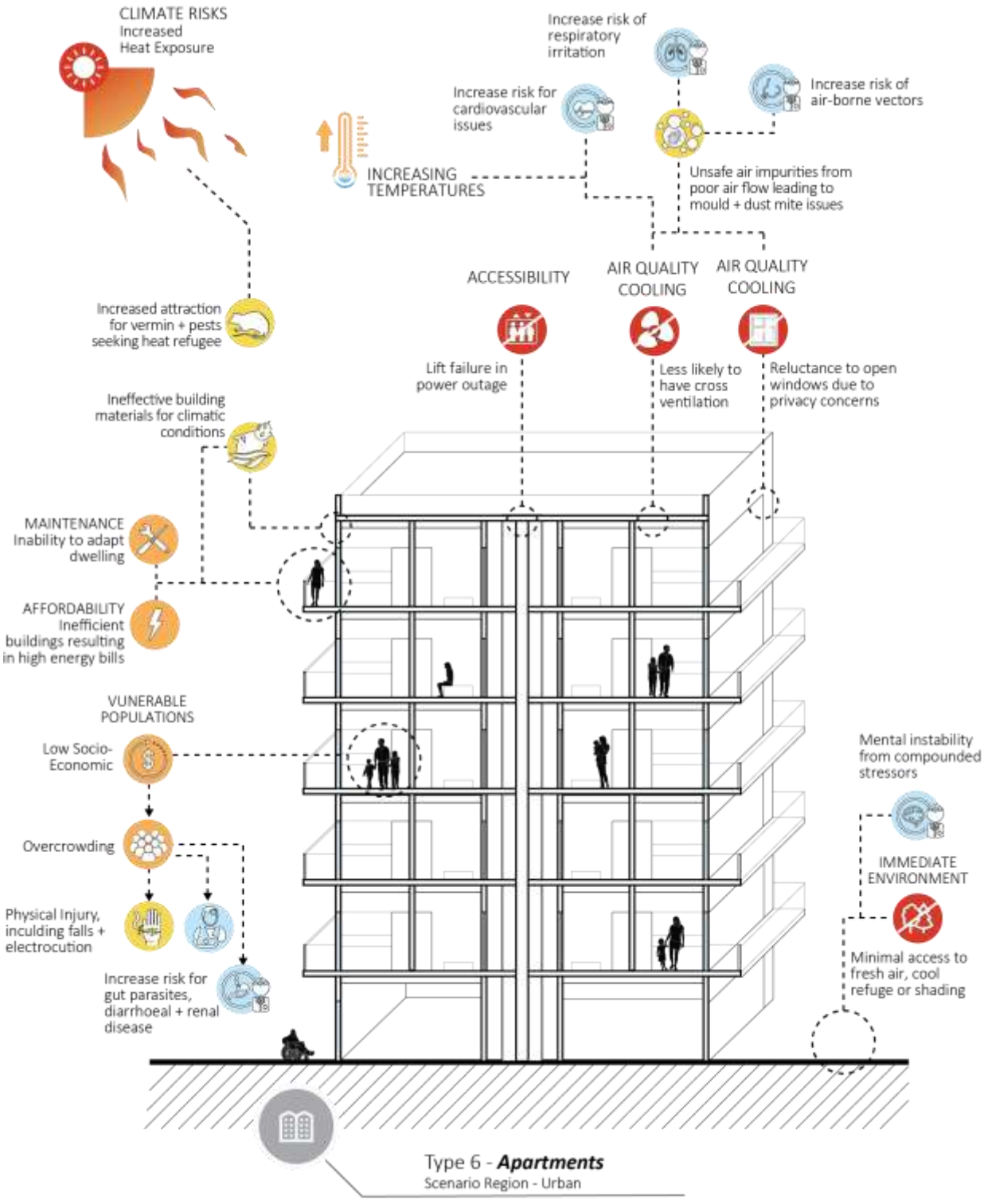

Figure 20: Climate-related health risks of Apartments (Type 6)
Source: the authors, building on NARCLiM data