REFRAMING CLIMATE CHANGE THROUGH A PUBLIC HEALTH LENS

AUSTRALIAN NATIONAL INTERNSHIPS PROGRAM

Report prepared for the Conservation Council ACT Region

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This report explores the health and wellbeing of people and the environment in the Australian Capital Territory. Climate change poses a significant risk to the health of the land. This is the land of the Ngunnawal people whose sovereignty was never ceded. I pay my respects to Elders past, present and emerging. I recognise the continuing connection to land, sea and community of First Nations people across Australia and in the Ngunnawal/Canberra region where this report was researched and written.

Acknowledgements

I would like to thank the Conservation Council for welcoming me and supporting a research project of my interest. To Helen Oakley, thank you for providing guidance in aligning my project with the objectives and values of the Conservation Council. It has been a valuable experience in learning how to conduct independent research and to observe the operations of a local non-governmental organisation.

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Finally, I would like to thank my Mum, Nicola Spurrier, whose work in public health has inspired me to pursue this field of research throughout my university studies.

Executive Summary

Humanity's survival and longevity depends on the state of Earth's natural systems. Despite this, humanity is creating our own demise through activities that are fuelling unprecedented climate change. Earth's resources have been exploited for human benefit and this consequentially is jeopardising both the health of humanity and the health of the planet. As illustrated in this report, anthropogenic climate change is yielding severe environmental threats that have the potential to cause severe morbidity and mortality. It is imperative to identify what these threats are and how they can be addressed.

This report explores the complex problem of climate change through a public health lens in the ACT. Desktop research informs a literature review in order to provide an overview of potential environmental threats, defined as hazards, in the ACT driven by climate change mechanisms. In the ACT, bushfires, heatwaves, drought and storm weather are all increasing in frequency and intensity. These hazards carry negative implications for population health in the ACT. Using the three-tier conceptualisation of climate change and health, it is seen that health impacts are both directly and indirectly influenced, and the severity of impacts on the ACT's population are exacerbated by socioeconomic factors. People with underlying health risks, Indigenous people, and people of low-income status, are evaluated as the most at risk to climate change health impacts. Similarly, these impacts are not equally distributed in the ACT due to geographical and infrastructure differences between suburbs.

There is an urgent need to advocate for policy that is, at its core, interdisciplinary and cognizant of the many factors that drive poor health impacts from climate change-driven hazards. The ACT is not immune to the health impacts of climate change so policy must work towards building a bio-sensitive ACT community. This requires an understanding of both health and environmental ways of thinking. Using a Systems Dynamics approach, the complex policy problem of climate change and health is emphasised. System Dynamics highlights the important difference between co-benefit and maladaptive policy. The former, co-benefit policy, is identified as the optimal policy strategy for the ACT. Similarly, the health co-benefits of climate change should be utilised by environmentalists and public health professionals alike to argue for stronger adaptive and mitigative climate action. The report concludes by emphasising the need for co-benefit policy and better recognition of the varied factors that influence health and climate change threats in the ACT.

We must consider the seasons of the year, and what effects each of them produces for they are not at all alike but differ much from themselves in regard to their changes

- Hippocrates 400BC

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Introduction

Problem Framing

The world is gripped by a climate crisis that is unequivocally anthropogenic. Human activities have caused an estimated 1°C of warming above pre-industrial levels. Mean global temperatures may reach a 1.5°C to 2°C increase by 2030 to 2052 if current warming trends continue (IPCC, 2018). Climate change is of particular concern to the global health community, who have long recognised the close relationship between the state of the environment and health outcomes (Martens et al., 1997). The Australian Medical Association has declared climate change a pressing health emergency, acknowledging that changes to Earth's natural systems will have severe consequences for disease burdens (Australian Medical Association, 2015). Extreme climatic variability, with its implications for health and wellbeing, indicate an immediate need for adaptive and mitigative policy that address both the environmental and public health risks of climate change.

Research Aims

This research report aims to identify the climatic trends in the Australian Capital Territory (ACT) and the implications these changes have on health and wellbeing. Since climate change will have major impacts on population health, it is a 'wicked problem' for policymakers. That is, it is complex, time-pressured, and characterised by multiple feedback loops and unknowns (Head, 2008). This report therefore places health as a desirable outcome for environmental policy and seeks to reframe the climate emergency in the ACT through a public health lens. To provide genuine co-benefit policy solutions, a holistic understanding of the problem is necessary.

Methodology

Using primary desktop research methods, the report conceptualises human-environment relationships and summaries the many ways in which climate change affects health. Using data on climate change threats in the ACT, direct and indirect health impacts are identified. Given the complex nature of the problem, Systems Dynamics are introduced as a methodology to illustrate the importance of co-benefit policy solutions. The reported is complemented by a number of informal conversations with public health and environmental policy professionals, who helped shape the interdisciplinary nature of this report.

Part 1: The Anthropocene and Human Health

The Anthropocene

Since the Industrial Revolution, there has been a profound shift in the way humans interact with the natural environment (Dearing et al., 2006, Boyden, 2013). Over time, these interactions greatly improved the health and wellbeing of humanity and transformed socio-economic systems. Key metrics indicate significant improvements in living standards. Since 1900, the global average life expectancy has more than doubled to 80 years and infant mortality rate has dropped from 65 deaths per 1000 live births to 29 deaths per 1000 live births in 2018 (Roser et al., 2013, World Health Organization, 2021). These changes in morbidity and mortality stem from the dramatic advances in agricultural and technological development, which in turn improve socio-economic standards of living (Hansen and Prescott, 2002).

However, these development gains have come at an environmental cost. Earth's natural systems are increasingly being pushed to extremes not previously seen during humanity's history (Steffen et al., 2018). Figure 1 shows the clear correlation between socio-economic trends and earth-system decline.

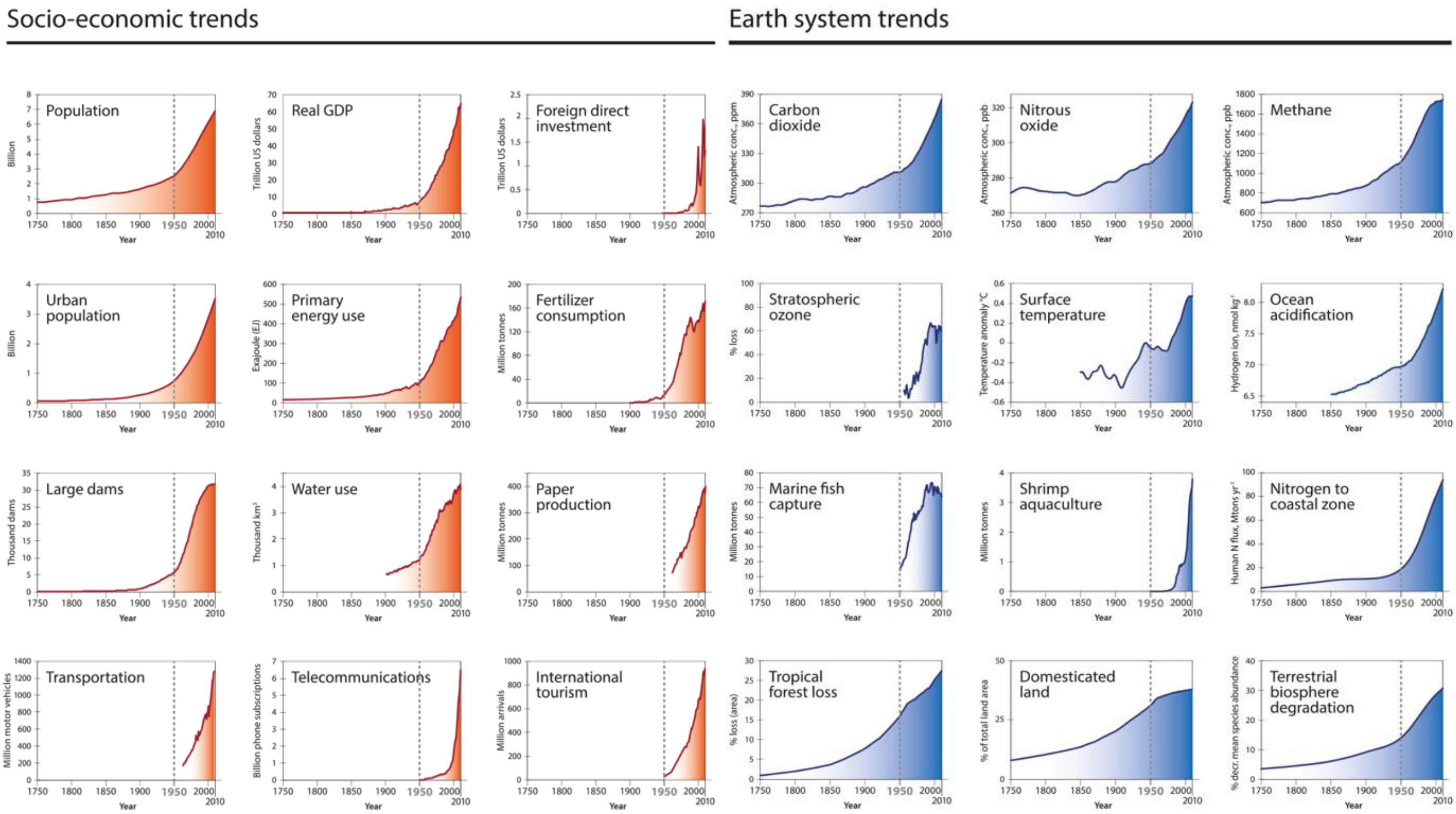


Figure 1: *Trends from 1750 to 210 in globally aggregated indicators for socio-economic development (socio-economic trends) and in indicators for the state of the Earth System (Steffen et al., 2015a)*

Researchers have defined this era as the Anthropocene; an era where accelerated ecosystem change is driven by human activity (Lewis and Maslin, 2015, Ruddiman, 2013). Humanity's ecological footprint, driven by the IPAT formula of sustainability (Impact = Population x Affluence x Technology), is the catalyst for the unprecedented changes to the earth's natural systems (York et al., 2003). Increased greenhouse gas emissions, fuelled by changing land management regimes and humanity's appetite for resources, impose irreversible changes to the earth's natural systems (Zalasiewicz et al., 2010). Whilst resources have provided genuine social and economic development, continued unsustainable exploitation of ecosystem services jeopardises both the health of the earth and the health of humanity for generations to come (Steffen et al., 2015a). It is clear there is a paradox between human benefits from the environment and its destruction and deterioration.

The Anthropocene is characterised by the transgression of planetary boundaries, which triggers irreversible environmental change (Steffen et al., 2015b). The planetary boundary framework (see figure 3) defines the environmental limits for humanity to survive. Of the nine boundaries, the threshold for a safe operating space has been crossed by four environmental factors, including climate change (Steffen et al., 2015b). Climate change is driven by atmospheric carbon dioxide (CO_2) concentrations. An increase in CO_2 enhances the natural greenhouse effect, trapping heat at Earth's surface. CO_2 levels are now rising beyond the levels for a safe-operating temperature space (Stockholm Resilience, 2021). Feedback mechanisms of the climate-carbon cycle influence mean annual temperatures, which in turn accelerate and intensify environmental forces that create a palpable risk to humanity's survival (Friedlingstein, 2015).

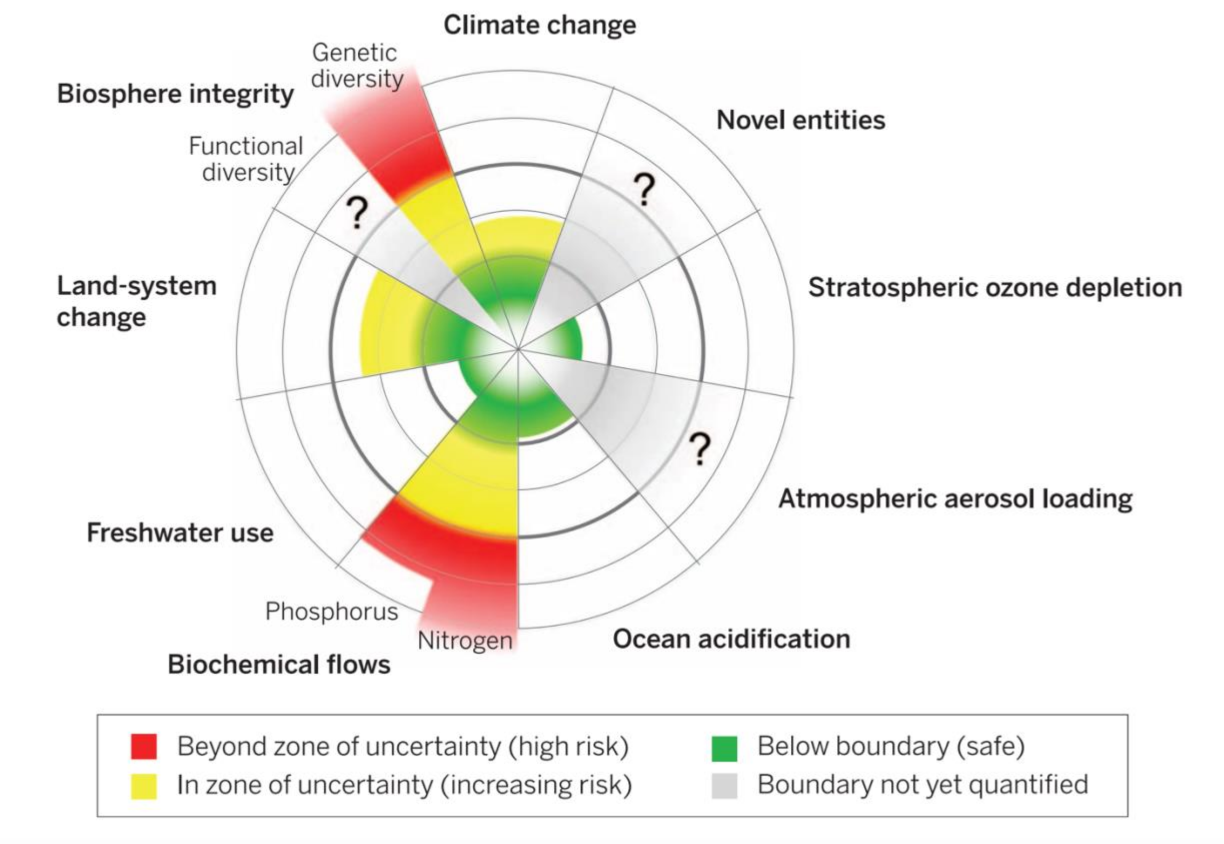


Figure 3: *Conceptual diagram of the current status of the planetary boundaries control variables. The control variable for climate change is atmospheric CO_2 concentration (Steffen et al., 2015b).*

Summarised in table 1, climate change has the potential to cause wide-ranging environmental impacts in Australia.

Table 1: *Potential environmental impacts of climate change in Australia. Author created using evidence from (IPCC, 2018).*

	CLIMATE CHANGES	POTENTIAL ENVIRONMENTAL OUTCOME
CARBON CYCLE	Increased CO_2 trapped in atmosphere	▪ Damage to biodiversity land and ocean ▪ Reduced air quality ▪ CO_2 feedback loop from permafrost melt
LAND TEMPERATURE	Rising temperatures, creating more hot days and increasing the frequency and severity of heatwaves	▪ Loss of arable land ▪ Changes to vector prevalence ▪ Increased pollen production ▪ Proliferation of microbes
OCEAN TEMPERATURE	Increased ocean temperature	▪ Coral bleaching and loss of ocean ecosystems ▪ Ocean current changes
SEA LEVEL	Sea level rise of 0.52-0.98 metres by 2100	▪ Loss of coastal land ▪ Storm surges ▪ Aquifer salinity
HYDROLOGY	Sea temperatures rising increases precipitation, weather extremes and rainfall variability	▪ Increased frequency and severity of floods, cyclones, droughts and bushfires ▪ Southern Oscillation dominant

Health Impacts of Climate Change

The health impacts of climate change are numerous and wide-ranging (Woodward et al., 2014). Morbidity and mortality occur as a result of environmental changes that create hazards to human health. Hazards are the environmental forces that carry potential to inflict harm to human health and wellbeing (Kates, 1976, Sauerborn and Ebi, 2012). Table 2 outlines climate change influenced hazards that may cause adverse health outcomes in Australia.

Table 2: *Potential health impacts from climate change hazards in Australia. Author created using evidence from (Woodward et al., 2014).*

CLIMATE CHANGE HAZARDS	POTENTIAL HEALTH IMPACT
EXTREME WEATHER EVENTS	Injuries, infectious diseases, mental health trauma, exposure to pollutants, malnutrition from agricultural impacts
TEMPERATURE INCREASE	Heat related illnesses, changes to vector ecology increasing infectious disease rates, increased food- and water- borne diseases
AIR POLLUTION	Respiratory tract infections, exacerbation of chronic diseases
INCREASED OCEAN TEMPERATURE AND ACIDITY	Malnutrition from loss of fish stock
SEA LEVEL RISE	Conflict, mental health, socio-economic status decrease from loss of land

Table 2 is not a complete nor comprehensive outline of health risks from climate change hazards. Predicting public health outcomes is complex and the links between an environmental force and a health outcome is dependent on many variables (World Health Organization, 2008). However, attempts have been made to simplify and categorise health risks to support policy decisions at local levels and to define the differences between direct and indirect health impacts (Whitmee et al., 2015) One particular conceptualisation is categorising the health impacts of climate change into three levels (Butler and Harley, 2010).

Primary

At the primary level, morbidity and mortality are directly the result of an environmental hazard (Butler and Harley, 2010). For example, a climate change influenced heatwave directly causes heat-stress to a given population. Similarly, getting burnt in a bushfire mediated by climate change weather extremes is a primary impact.

Secondary

At the secondary level, morbidity and mortality are indirectly the result of ecologically mediated changes (Butler and Harley, 2010). This includes changes to the distribution and abundance of vectors and intermediate hosts that manifest in warmer climates (Campbell-Lendrum et al., 2015, Sutherst, 2007). This level includes diseases that spread from climatic influences on water-, air-, and food-borne diseases. One example in Australia, is the predicted rise in Ross-River Virus and Malaria, particularly in tropical regions as the optimal climate for vector spread (Bryan et al., 1996, Shocket et al., 2018).

Tertiary

At the tertiary level, health impacts materialise from climate change disruptions to social, economic, and political systems (Butler and Harley, 2010). This includes health issues related to population displacement, poverty and conflict which are exacerbated as a result of climate change mediated hazards. For example, climate change can create resource scarcity which is a causal factor for regional violence and conflict (Homer-Dixon, 1994). The tertiary impacts can multiply the primary and secondary impacts of climate change. For example, socioeconomic factors limit the capacity to adapt or seek necessary care for a climate-induced issue (Butler, 2014).

It is important to note that mental health issues like anxiety and depression often accompany the experience of climate change-induced environmental hazards. Thus, mental health can be linked to all three levels of climate change health impacts (Berry et al., 2010).These connections in the three-tier system are illustrated in figure 4, noting that the burden of disease at each level is dependent on the specific characteristics of each population.

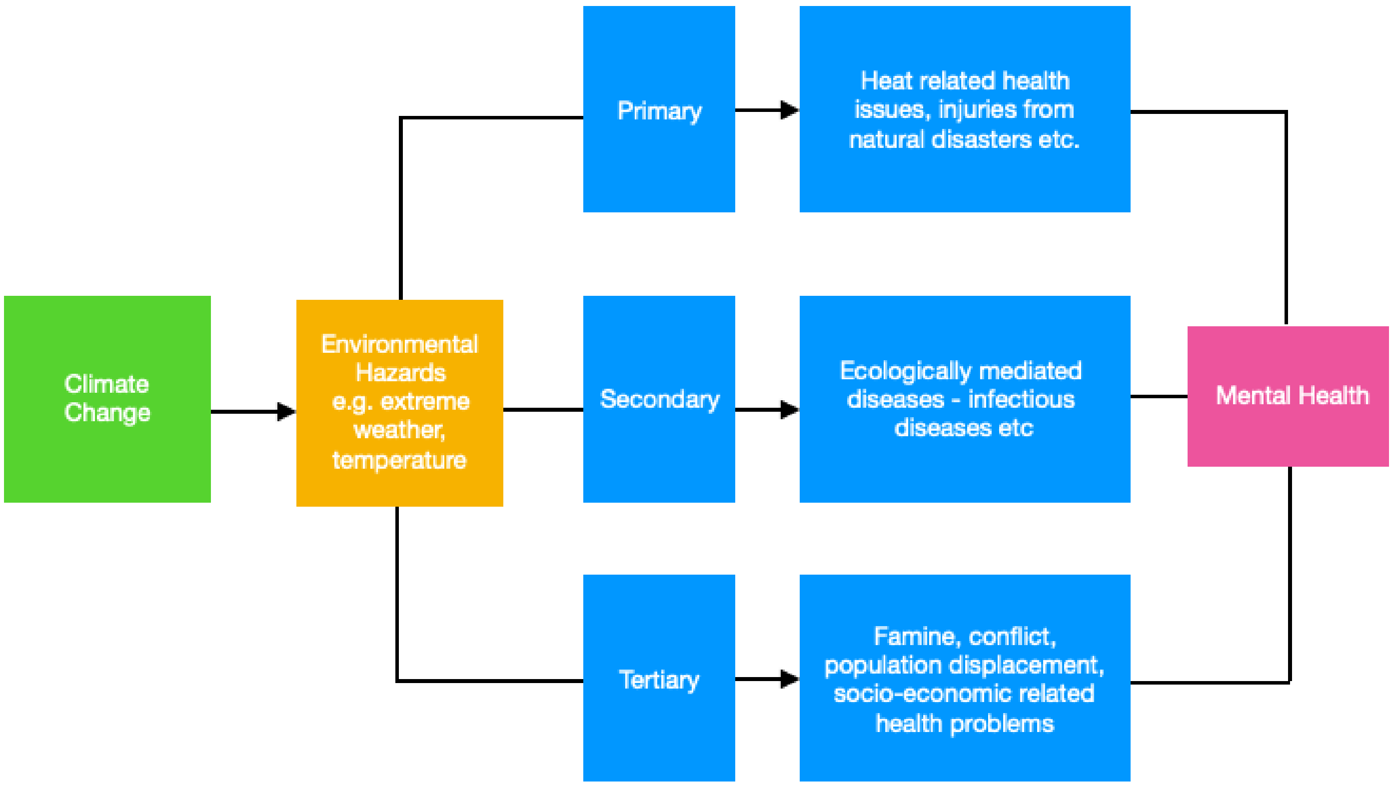
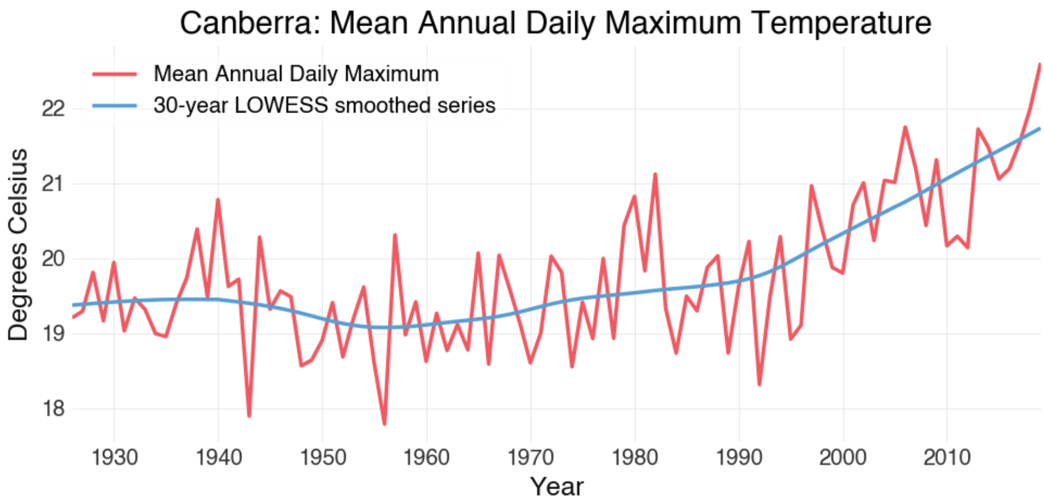


Figure 4: Linking the connections between climate change and health. Author created using the three-tier framework from (Butler and Harley, 2010).

Part 2: Climate Change and Health in the ACT

ACT Climate Trends and Environmental Hazards

The ACT is not immune to the environmental threats driven by anthropogenic climate change. Observed temperature trends show that since 1926, there has been a 1.5°C increase in mean maximum temperatures and a 2°C increase in mean minimum temperatures (figure 5) (Commissioner for Sustainability and the Environment, 2019). There is also a rising number of annual 'hot days' (above 25°C) (ACT Government, 2014). Regarding rainfall, the climate is becoming drier with shorter and more intense rainfall events (ACT Government, 2014). These climatic trends increase the likelihood of environmental hazards that could in turn seriously endanger human health and wellbeing in the ACT.



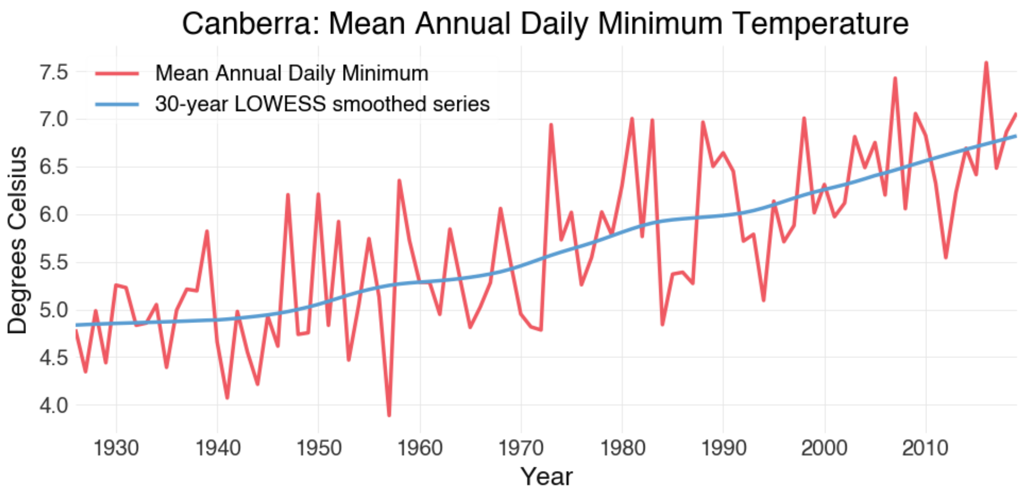


Figure 5: *Canberra's mean annual maximum and minimum temperatures since 1930 using data from the Australian Climate Observations Reference Network – Surface Air Temperatures (Palmer, 2020)*

Regional climate modelling of the ACT identifies four significant environmental hazards as a consequence of anthropogenic climate change (ACT Government, 2021b). They are as follows:

Bushfires

More fire danger days and a longer fire season are predicted (ACT Government, 2021b). The Forest Fire Danger Index (FFDI) bushfire danger in Australia. Evidence suggests that the ACT will have an annual FFDI average of 27.9 to 38.3 days of very high or extreme fire danger days by 2050. This is compared to the present average of 23.1 days (Hennessy et al., 2005). Whilst bushfires do play an important role in Australian forest ecology, the rising frequency and intensity of bushfires and risk of air pollution presents genuine hazards to the ACT (Steffen and Hughes, 2014). Moreover, bushfires release CO_2 emissions, creating a vicious feedback loop of climate change effects (Russell-Smith et al., 2007). Figure 6 indicates the bushfire prone areas in the ACT.

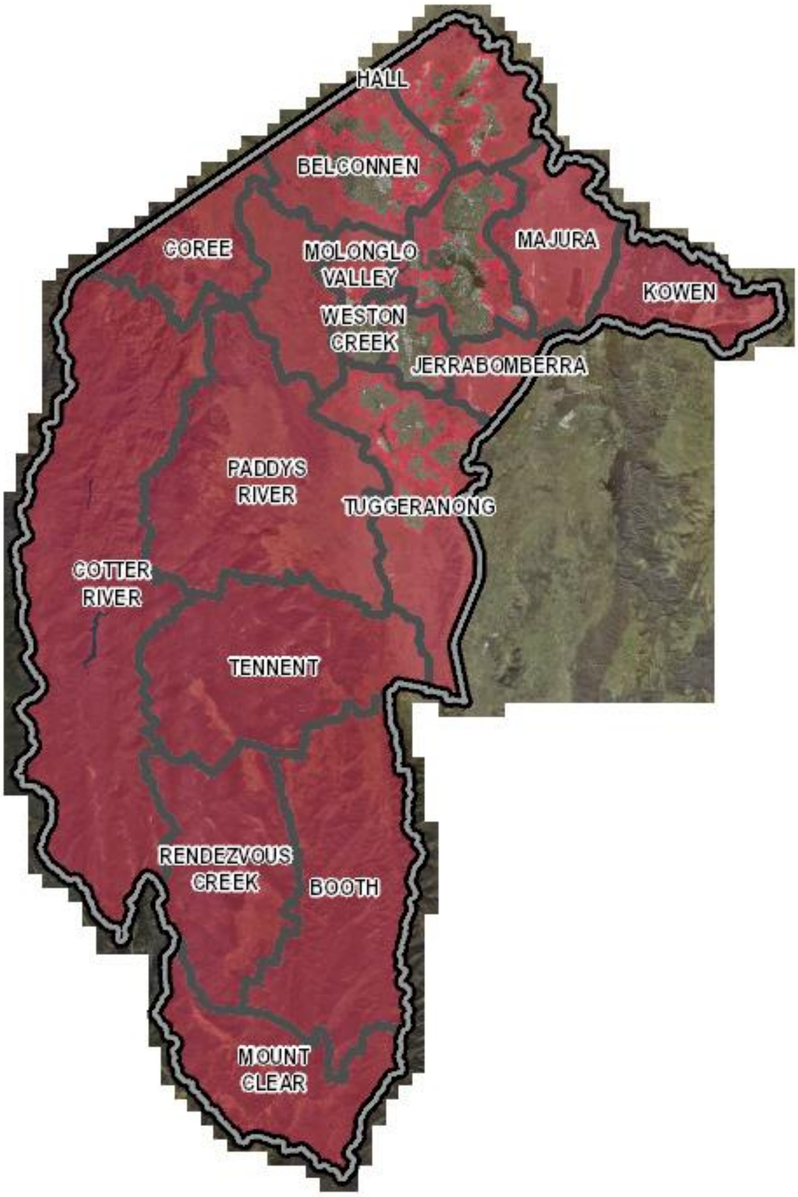


Figure 6: *Map of bushfire prone areas in the ACT (ACT Emergency Services, 2021)*

Heatwaves

Heatwaves are defined as periods (generally at least three days) of unusually high temperatures (ABC News, 2014). Heat thresholds differ between population groups (Arbuthnott et al., 2016). In the ACT, the number, duration and intensity of defined heatwaves has increased from baseline levels (ACT Government, 2014). Urban areas with fewer greenspaces are more susceptible to increased heat due to the phenomenon of urban heat islands (Iping et al., 2019). The 2019-2020 summer was the ACT's hottest summer on record (Bureau of Meteorology, 2020a).

Droughts

The ACT's climate is relatively dry with hot summers and cold winters (Bureau of Meteorology, 2019). Rainfall is generally evenly distributed with a long-term monthly average of 50-75mm (Bureau of Meteorology, 2019). However, increasing temperatures and reduced precipitation trends indicate a greater vulnerability to drought conditions. Droughts are expected to be more prolonged and frequent (ACT Government, 2014). They are a contributing factor to increasing bushfire weather (Steffen et al., 2019)

Storm Weather

Climate change fuels more intense and damaging storms, which includes cyclones, extreme rainfall, hail and thunderstorms (Murphy and Timbal, 2008). Storm weather is now occurring with more intensity and carrying greater moisture as a result of climate change processes (Bureau of Meteorology, 2020b). In the ACT, storm weather is expected to be more frequent and severe over a longer summer season (ACT Government, 2021b). The 2020 Canberra hailstorms are an example of increasing storm weather patterns.

ACT Health Impacts from Climate Change Mediated Hazards

Bushfires, heatwaves, droughts and storm weather all have direct and indirect health impacts. In the ACT, whilst limited existing data is available, health impacts can be extrapolated from the climatic trends. Given the hypothesising nature, many health impacts are yet to be realised in the literature. The following section links the four identified hazards to potential health impacts in the ACT.

Bushfires

The immediate and direct health impacts of bushfires is obvious. At the direct and primary level, radiant heat poses a significant threat as exposure can cause severe burning to the skin (Johnston, 2009). Bushfire heat can cause severe dehydration and heat exhaustion (Dennekamp and Abramson, 2011). Smoke inhalation is a direct health impact that also has the potential to affect populations hundreds of kilometres away from the source of fire as smoke diffuses across the atmosphere (Ohneiser et al., 2020). Smoke inhalation can cause or exacerbate respiratory and cardiovascular disease. During the 2019-2020 summer bushfires, smoke in the ACT was linked to 31 deaths and 229 hospital admissions (Borchers Arriagada et al., 2020). Land and water contamination by particulate matter deposited by fire can impact health (White et al., 2006). Indirectly, health problems emerge from population displacement, increased rates of violence, and a loss of economic security. Moreover, the mental trauma from bushfire is ongoing.

Heatwaves

Heatwaves are believed to have killed more Australians than any other environmental hazard (Coates et al., 2014). Heatwaves cause physiological stress to the body, resulting in health impacts from the mild heat rashes to severe cases of heatstroke (Arriagada et al., 2020). Increased heat heightens the risk of dehydration placing a burden on the cardiovascular and renal systems (Cheng et al., 2019). Long episodes of extreme heat limit the ability to exercise which is integral for wellbeing. Specific to Canberra, warmer temperatures favour the growth of toxic blue-green algae found in lakes (Environmental Protection Agency, 2013). Exposure can cause diarrhoea, nausea and skin irritation. Extended periods of extreme heat pose a salient risk to mental health (Hansen et al., 2008).

Droughts

Droughts pose a significant threat to health, although health impacts are predominantly indirect. Reduced water flows can increase the concentration of harmful pollutants, compromising the availability of potable water (Nilsson and Renöfält, 2008). Several studies show links between waterborne diseases and drought events (Funari et al., 2012, Levy et al., 2016, Maurizio and Roberta, 2017). Food insecurity is often caused by droughts resulting in under- and malnutrition (Barrett, 2010). Although there is limited arable land used for food production in the ACT, droughts in other parts of Australia pose a risk to the ACT's food supply, with the potential to reduce the availability of fresh, healthy and affordable food. The effects of prolonged droughts on mental health are far-reaching, and include an increased risk of suicide (Edwards et al., 2015).

Storm Weather

Storm weather has a direct impact on built infrastructure. During storm weather, hazards such as flooding present an immediate danger and flying debris may result in injury (Few, 2013). Storm weather increases the likelihood of water contamination, potentially leading to increases in infectious diseases (Andrade et al., 2018). In the 2020 hailstorm event, there were almost 131,000 insurance claims from the damage of the storm (Brown, 2021). Damages to shelter and personal belonging can cause mental stress due to sudden loss of economic security or loss of personal value items.

Demographic Vulnerability

Certain population groups are more at risk of the health impacts of climate change, for example children, the elderly, those with underlying health conditions, and people with fewer economic resources (Denton, 2002, Otto et al., 2017).

Underlying Health Conditions

People with pre-existing health conditions may be at greater risk of health complications presented by environmental hazards. For example, a person with asthma is more likely to experience severe morbidity or mortality from bushfire smoke than someone without asthma (D'amato et al., 2015). Persons with chronic health problems like multiple sclerosis often experience worse symptoms during periods of excess heat (Bol et al., 2012).

Socioeconomic Determinants of Health

The socioeconomic determinants of health explain how factors like employment, housing and education affect a person's health (Kawachi and Kennedy, 1997). Although the ACT has a relatively affluent population there are almost 26,000 residents who live below the poverty line (ACT Council of Social Services, 2019). Poverty leads to worse health outcomes and limits the ability to access health services particularly in times of environmental disaster (Hallegatte et al., 2018). Housing is one factor that confers a disproportionate distribution of risk and vulnerability to the health impacts of climate change. A 2018 study found that 36% of residents in the ACT live in homes poorly designed for warmer temperatures and a further 23% of residents cannot afford cooling solutions (Schirmer and Yabsley, 2018). People living in new urban developments on the outskirts of Canberra are more susceptible to the health impacts of heat due to lower tree cover density (ACT Government, 2021b). Suburbs of higher wealth typically have more greenspace and are more resilient to the effects of urban heat

First Nations People

The health burden of climate change disproportionality impacts Indigenous Australians (Green et al., 2009). Vulnerability is increased due to general lower socioeconomic status and the intergenerational effects of colonisation (Green et al., 2009). Indigenous peoples have higher rates of pre-existing cardiovascular and respiratory disease, further increasing vulnerability (Johnston et al., 2007). Moreover, there is a distinct lack of culturally appropriate medical services across Australia (Durey, 2010). Given Indigenous people's wellbeing is directly linked to the health of Country, the health of the Ngunnawal people in the ACT will likely be disproportionately impacted if climatic trends continue to damage the environment (Commissioner for Sustainability and the Environment, 2019).

Figure 7: *The socioeconomic determinants of health framework. Author created using evidence from (Pittman, 2020).*

Part 3: Co-Benefit Policy Solutions

The Goal of Bio-Sensitivity

The health impacts of climate change present an overwhelmingly complex policy problem. Significant efforts need to be made to reduce global emissions in order to mitigate against the worst-case future scenarios of global warming (IPCC, 2018). Similarly, there is rationale to implement protective public health policies. However, oftentimes policy exists in silos and fails to consider the breadth of its causal effects (Leiren and Jacobsen, 2018). This is particularly problematic when considering the causal relationships between human-environment interactions in the face of anthropogenic climate change. There is an identified need to implement adaptive and mitigative policy that is considered both environmental and public health focused.

Firstly, in order to understand the type of policy required, there needs to be recognition of the overall goal policy should work towards. Boyden presents the concept of bio-sensitivity, which is the belief that every society should equally promote health and wellbeing for humanity and for the planet (Boyden, 2016). It places human outcomes on an equal footing with environmental outcomes, which encourages harmony between human-environment relationships (Tait, 2018). Policy addressing the health impacts of climate change must be cognizant of the impact policy has on the environment and potential for future greenhouse gas emissions. Policy should be in line with the principles of bio-sensitivity.

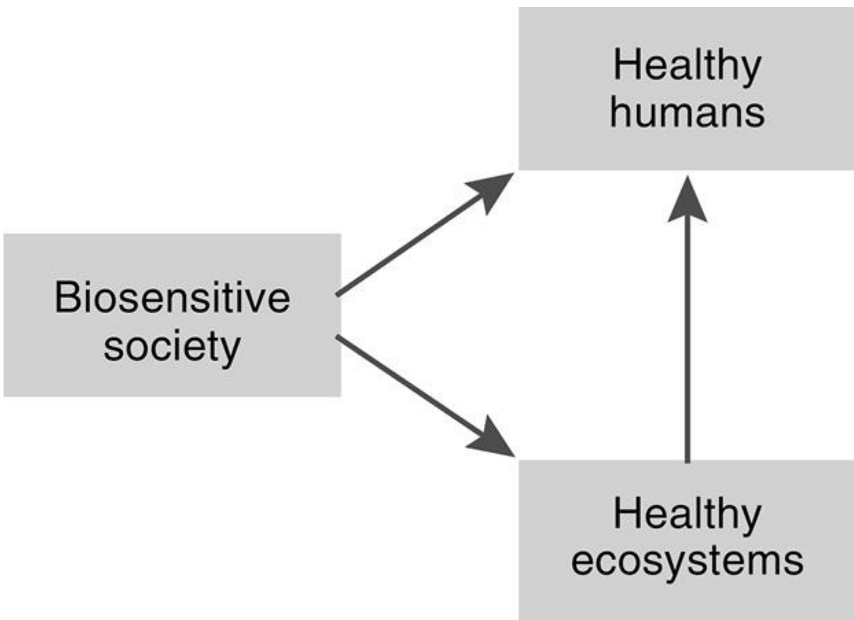


Figure 9: *The framework of a bio-sensitive society (Boyden, 2016)*

Co-Benefits

Co-benefits policy offers a solution that recognises the importance of bio-sensitivity. Co-benefits are defined as the ancillary benefits to health that arise when implementing climate change policies (Haines, 2017). Table 3 presents a brief overview (not comprehensive) of climate change mitigation and adaptation strategies that result in health co-benefits. Mitigation strategies aim to reduce rising temperatures as a result of increasing greenhouse gas emissions (VijayaVenkataRaman et al., 2012). Adaptation strategies are attempts to adjust human systems to the environmental threats (bushfire, drought, heat, storm weather) that are mediated by rising temperatures (VijayaVenkataRaman et al., 2012).These strategies are in line with the goals of bio-sensitivity and could be encouraged in the context of the ACT.

Table 3: *Examples of mitigation and adaptation strategies to climate change and the potential health co-benefit. Author created using evidence from (Smith et al., 2014) and (Kjellstrom and Weaver, 2009)*

MITIGATION STRATEGY	ADAPTATION STRATEGY	HEALTH CO-BENEFIT
Improved public transport options (reduced overall vehicle use)		More walking/cycling, encouraging exercise and reducing obesity
Decreased dependence on fossil fuel resources		Cleaner air, less respiratory and cardiovascular disease
Increased fruit and vegetable consumption and reduced meat consumption		Reduced obesity, lower rates of cancer, improved nutrition outcomes
Improve building code to improve energy efficiency		Reduced risk of hyper- and hypothermia
	Increasing urban green space	Mental wellbeing improves, encourages outdoor exercise reducing obesity
	Bushfire and storm weather early warning systems	Better health protection systems reducing impact on the health system in times of disaster
	Improved food handling practices	Reduction of food-borne diseases
	Emergency and business continuity planning	Strengthen resilience to economic instability

	Social benefit schemes for vulnerable persons	Strengthen resilience to economic instability, mental health
	Indigenous culturally appropriate medical services	Reducing rates of underlying health conditions, mental health
	Water security infrastructure	Reduction of water-borne diseases

Co-Benefits vs Maladaptation

Co-benefit policy is further defined as effective adaptation (Smith et al., 2014). A growing body of research suggests that a number of climate change policies are ineffective and thus maladaptive (Barnett and O'Neill, 2013). Maladaptation is defined as a strategy that has potential to exacerbate vulnerability to climate change (Juhola et al., 2016). For example, the implementation of air-conditioning units (specifically ones that use non-renewable energy sources) are considered a maladaptive behaviour. This is because whilst it reduces body temperatures, it also produces greenhouse gas emissions which in turn fuels the cycle of climate change, rising temperatures and the need for cooling solutions. Maladaptation is in direct opposition to the framework of bio-sensitivity as it fails to recognise the interrelationships between the environment and health and variables affect one another.

In order to demonstrate human-environment relationships and the difference between co-benefit solutions and maladaptation, a Systems Dynamics approach can be useful.

Systems Dynamics

Methodological approach using causal diagrams to demonstrate the non-linear behaviour of complex systems where variables interact and change over time.

The first causal loop diagram presented in figure 10 shows the relationships between the state of the ACT's environment, public health and wellbeing, and the dependency on a specific strategy (activity or technology) designed to influence human-environment interactions. Each arrow, defined as a causal link, is labelled to correspond to the included information table (table 4). The table defines the change that each causal link represents.

The Systems Dynamics approach taken follows the methodology outlined by Proust et al., 2012 in their application of the method in urban environments and the author's prior knowledge of the method.

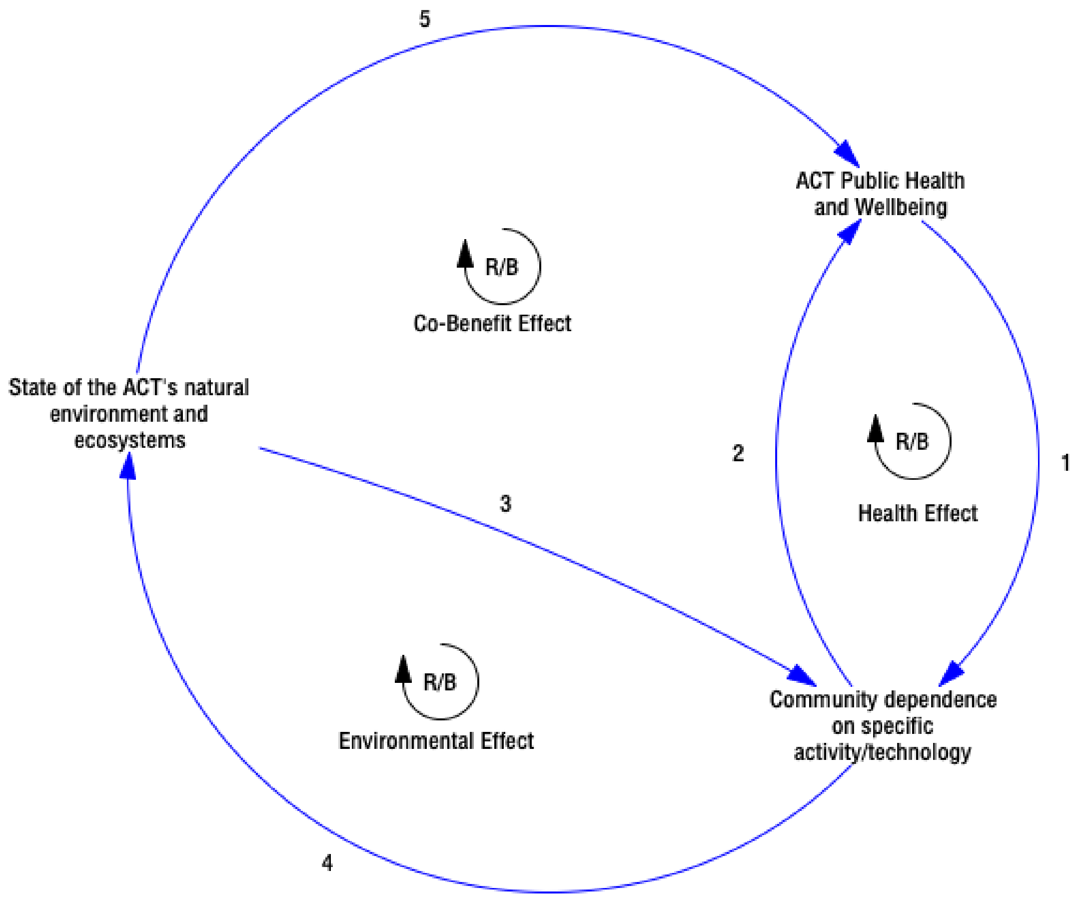


Figure 10: Systems Dynamics intermediate diagram of the health and climate change effects in the ACT. The arrows/links are labelled with numbers that correspond to Table 4. Author created.

Table 4: The causal links of Figure 10.

LINK	PROCESS REPRESENTED
1	Policies that attempt to change human behaviour, i.e., dependency on a specific activity or technology. For instance, the dependency on using cars or air-conditioning units.
2	The process where the activity/technology affects human health and wellbeing.
3	Implementation of policies that attempt to change the community’s dependency on an activity/technology.
4	The ongoing use of a technology or behaviour that affects the state of the ACT’s environment.
5	The process of the state of the ACT’s environment affecting human health and wellbeing.

The symbol R/B indicates whether the loop is reinforcing or balancing which is dependent on the net polarity effect of each causal link. The net effect of the processes in figure 10 is dependent on the polarity given. Polarity describes whether the variables at the two ends of the link move in the same direction (+) or opposite directions (-). For example, if measuring decreasing health and wellbeing causally linked to a reduction in environmental wellbeing, a positive (+) would be assigned.

In figure 10, if links 2 and 4 are given positive (+) polarity, the process would work towards improving both the health of the ACT's environment and the health of the ACT's population. This demonstrates a technology or activity that falls under the category of policy working towards co-benefits. Alternatively, when links 2 and 4 are given negative (-) polarity, the processes work to undermine the health of the ACT's environment and the health of the ACT's population. In this case, the risk of maladaptation is high.

To better demonstrate a specific system of interest in the ACT, a causal loop diagram has been built focusing on heatwaves, one of the identified environmental hazards from climate change. In this diagram, heatwaves are represented by the **number of annual hot days,** which is the measure of the state of the ACT's natural environment. Health and wellbeing are represented by the **incidence of cardiovascular disease**, which is commonly affected by heat-stress. **Individual dependence on private vehicles** is defined as the indicator of community dependence on a technology or activity. In addition, further variables have been included to better illustrate interconnectivity. **Extent and quality of active transport** is included to show co-benefit policy that influences the dependency on private vehicles. **Extent and quality of green space** represents policies that mitigate against urban heat effects and influence dependency on private vehicles. **Aggregate vehicle kilometres travelled** helps assess the overall use of vehicles by the ACT population, which in turn is the mechanism that produces emissions, influencing the number of hot days.

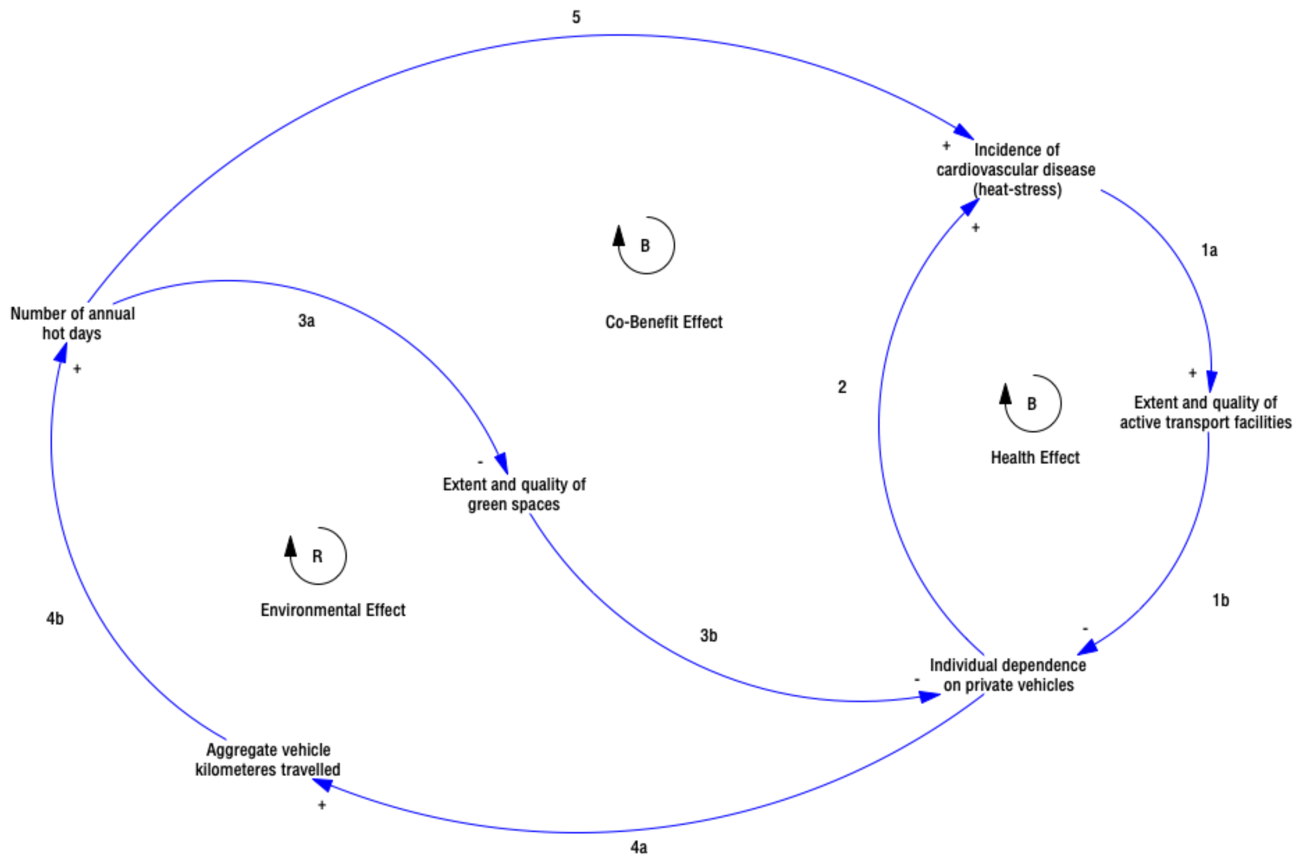


Figure 11: A causal loop diagram of the links between heatwaves, health, and human activity. The arrows/links correspond to the numbers in Table 5. Author created.

Table 5: The causal links of Figure 11.

LINK	PROCESS REPRESENTED
1a	Active transport policies like bike paths and public transport. This process is driven by the knowledge that exercise reduces cardiovascular and respiratory disease.
1b	The decision of an individual to use the active transport facilities.
2	The impact of reduced physical activity. Driven by the decision not to use active transport. Increased likelihood of obesity and subsequent respiratory and cardiovascular disease.
3a	The implementation of infrastructure and policies that influence green spaces in the ACT.
3b	The attractiveness of green spaces to promote individuals' decisions to use active transport instead of driving a car.
4a	The activity of driving a car.
4b	The total ACT's population contribution to greenhouse gas emissions from using diesel or petrol fuelled vehicles.
5	The impact of a heatwave on health and wellbeing. Heat as the cause of hyperthermia.

The causal loop diagram shows a clear feedback structure where variables interact with each other over time. Firstly, concerning the health effect balancing loop, it is seen that by promoting policies that encourage active transport, the incidence of cardiovascular disease is decreased. This is influenced by the individual decision to choose vehicular travel over active travel and could be further influenced by a number of external factors such as weather, attractiveness of the active transport facilities, and physical fitness levels. Link 2 shows that if dependence on vehicles is high, then the incidence of disease is also high or the alternative, if dependence on vehicles is low, the incidence of disease is decreased. Secondly, the environmental reinforcing loop shows clearly the connections between vehicles emissions produced and the number of hot days. Links 3a and 3b show the process of policies that encourage urban green spaces to promote active travel and reduce urban heat effects. Finally, the co-benefits balancing loop, shows that the number of hot days influences the rate of disease, which further influences the activities creating the number of hot days and the impact this has on an individual's decision to choose active travel over driving a vehicle.

Figure 11 helps shows that co-benefit adaptive strategies are needed to reduce the community's dependence on vehicles. These policies would need to promote active travel to gain the health co-benefit by providing green spaces and active transport necessary to influence individual decision making. Similarly, health co-benefits policies are less likely to become maladaptive.

Co-Benefits in the Australian Political Landscape

The ACT is one of the leading jurisdictions in Australia for climate action. Australia has some of the highest emissions per-capita worldwide, but ACT emissions are slowly decreasing (Keywood et al., 2016). This is in part due to progressive policy action that has seen the ACT reach 100% renewable energy through investment in solar and windfarms in 2019-2020 and commit to a net-zero emissions target by 2045 (ACT Government, 2021a). However, the positive trend towards climate action does not mean that there is no further opportunity to review how environmental policy is framed in the ACT. This is particularly important given the Federal government inaction on climate change policy.

The health co-benefits of climate action present an opportunity to reframe environmental policy in the ACT and Australia. It can support advocacy groups and activists to reframe the way in which climate policy is communicated, with the potential to change the perspectives of those sceptical to climate action. However, the co-benefits of climate action are often overlooked in policy (Karlsson et al., 2020). A suggested reason for this is the lack of clear, interdisciplinary thinking. Problems and their solutions exist in silos (Leiren and Jacobsen, 2018). This is suggested to firstly be because a lack of expertise within and outside government in interdisciplinary ways of thinking and secondly because of the long-term nature of complex, wicked problems (Workman et al., 2016). Highlighting the advantages of co-benefits can support strengthening action on climate change

Addressing a Complex, Wicked Problem

One of the issues with wicked problems, like climate change, is that the benefits of a policy are typically only visible much later in time, sometimes many generations later (Mayrhofer and Gupta, 2016). Similarly, the cost of policy inaction can be unfairly distributed, borne by those who have the least role in creating the problem. This is exemplified by the greatest impacts of climate change being on developing countries who have contributed least to its causation (Handmer et al., 1999). There is a spatial and temporal difficulty in addressing complex, wicked problems (Mayrhofer and Gupta, 2016). Co-benefits are therefore useful to help align the temporal and spatial differences across populations and regions, improving the likelihood of policymakers realising the local benefits (Mayrhofer and Gupta, 2016).

In addition, co-benefits provide a comprehensive picture to policymakers, who may fail to understand the varied costs of inaction (Karlsson et al., 2020). Using the framework of Systems Dynamics, co-benefits can be illustrated to policymakers as a useful strategy when responding to a problem with many changing variables.

Overcoming Political Challenges

In Australia, there is an ideological challenge in communicating the impacts of climate change (Fielding et al., 2012). There is a real challenge in communicating the impacts of climate change as climate science scepticism persist, fuelled by political voices advocating for new coal stations and investment into gas extraction. Similarly, environmentalism in Australia has been routinely vilified by politicians and the media, which in turn has resulted in Australia lagging behind on climate action policy (Tranter, 2012). A focus on neoliberal ideology, which pertains to the narrative that the environment is to be exploited for short-term gain, is prominent in Australian politics (Coffey and Marston, 2013). Therefore, co-benefits can be presented as a solution to overcome this ideology-driven barrier to climate action (Mayrhofer and Gupta, 2016). Those unconvinced by the need for climate action from an environmental standpoint may be more inclined to support policies that are communicated as beneficial to health outcomes. In Australia, health is continually seen as one of the top bi-partisan election issues that voters care about (McAllister et al., 2019). Comparably, emissions reductions, whilst it is a growing election issue, is sharply divided along political party lines, age groups, and gender (Colvin and Jotzo, 2021). By reframing environmental action and climate change through a public health lens, there is potential for the ideological barrier to be overcome and to gain broader support across Australian voters.

Conclusion and Recommendations

There are many ways in which climate change will impact health in the ACT. The four identified hazards show that health can be impacted directly or indirectly, with the burden of disease more likely for people with underlying health conditions or at risk to economic loss. The situation presents a complex policy problem for environmental and public health advocates. This report concludes by summarising the key messages of reframing climate change through a public health lens.

1. Policy needs to work towards building a bio-sensitive ACT.
2. Systems Thinking is a useful methodology in evaluating the causal drivers of climate change and public health and helps to avoid maladaptive solutions.
3. The advantages of co-benefits should be used to communicate the health impacts of climate change and encourage stronger climate action.

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