,

CITY OF MELBOURNE

REPORT: Review of Health and Climate Change Literature

To inform City of Melbourne Zero Net Emissions Strategy

28 June 2018

Report prepared by: Fiona Armstrong, Founder and Executive Director, Climate and Health Alliance

Acknowledgements

With thanks to Annabelle Workman and Rebecca Patrick for reviewing the draft and final report, and to Sue Cooke for editing.

Contents

Executive Summary

This report provides an overview of the evidence in relation to the health co-benefits associated with climate mitigation and adaptation strategies. It is intended to inform the City of Melbourne about the health and social benefits available from the implementation of initiatives to achieve its net zero emissions goal.

There are many benefits for the health and wellbeing of the population associated with strategies to reduce greenhouse gas (GHG) emissions. These health co-benefits, which either reduce current health threats or lead to improvements in current health status, can be realised at a local scale, and often in a very short time frame (days, weeks and months) whilst the climate benefits accrue in the longer term (years, decades and centuries).

Health co-benefits arise from a range of strategies to reduce emissions in a number of sectors. Reducing emissions in energy and transport sectors can reduce air pollution, which can lead to immediate improvements in cardiovascular and respiratory health, and results in fewer heart attacks and asthma attacks, and fewer hospitals admissions. Reducing the carbon intensity of our diets and food systems can also decrease heart disease, help avoid obesity and diabetes, and reduce the incidence of bowel cancer. Investing in green infrastructure lowers GHG emissions, and leads to positive improvements in mental, physical and social health.

These are just some of the opportunities that are currently under-recognised in the actions that individuals, communities, cities, states and nations are taking to act on climate change. While major emissions reduction targets may be set by national governments in accordance with international agreements, much of the effort to deliver the requisite emissions reductions will occur at the subnational and city level. A net zero emissions strategy for the City of Melbourne can achieve much more than just emissions reductions if carefully targeted interventions are used (see Appendix A for current initiatives in other jurisdictions).

While there are health co-benefits associated with both climate mitigation and adaptation strategies, the bulk of the literature reviewed here is in relation to the co-benefits associated with climate mitigation. Many climate adaptation and climate mitigation strategies can be mutually reinforcing and are generally considered to be most effective when pursued simultaneously (Landauer, 2015).

In additional to health and climate benefits, many climate mitigation and adaptation strategies also offer economic savings from avoided ill-health and productivity gains. These savings can often offset the costs of implementing the policy, and in some cases, the savings vastly outweigh the costs, offering health-climate-economic benefits: a win-win-win scenario. As such, the benefits of emissions reduction should be an integral inclusion as part of the systematic assessment and development of net zero emissions strategies.

There is more to do to evaluate the specific economic opportunities associated with health co-benefits associated with zero net emissions strategies proposed for the City of Melbourne. However, the evidence of the health co-benefits from climate mitigation is sound, and there should be no delay in seeking to implement initiatives to capitalise on the evidence outlined in this report.

1. Definitions

Ancillary benefits - the secondary or supplementary positive effects that a policy or measure aimed at a particular objective might have

Co-benefits - the positive effects that a policy or measure aimed at one objective might have on other objectives (IPCC, 2014b, p. 14). For example, the health and economic benefits achieved through reducing GHG emissions.

Climate action – action taken to mitigate or adapt to climate change either by reducing GHG emissions to prevent worsening climate harm, or adapting to those changes which are unavoidable.

Climate adaptation – the process of adapting to climate change in order to better cope with, manage or adjust to its impacts including changing conditions, stress, hazard, risk, or opportunity. This can happen at household, community, group, sector, region, or country levels.

Climate mitigation - includes actions taken globally, nationally and individually to limit changes in the global climate caused by human activities. Mitigation activities are designed to reduce greenhouse emissions and/or increase the amount of greenhouse gases removed from the atmosphere.

Climate altering pollutants – include greenhouse gases such as carbon-dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons (CFCs) and hydrofluorocarbons and other climate pollutants like black carbon.

Greenhouse gases – the main greenhouse gases are carbon-dioxide, water vapour, methane, nitrous oxide, ozone, chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs). Greenhouse gases trap heat in the atmosphere and the increasing levels in the atmosphere since pre-industrial times are responsible for the enhanced greenhouse effect or global warming.

Green infrastructure - the network of natural landscapes and features in urban settings. It can include parks and gardens, urban forests, street verges and footpaths, sports and recreational facilities, green roofs and walls.

Health - The World Health Organisation defined health in 1948 as a "State of complete physical, mental, and social wellbeing, and not merely the absence of disease or infirmity."

The 1986 Ottawa Charter for Health Promotion held that health is "The extent to which an individual or group is able to realize aspirations and satisfy needs, and to change or cope with the environment. Health is a resource for everyday life, not the objective of living; it is a positive concept, emphasizing social and personal resources, as well as physical capacities."

Health promotion - is the process of enabling people to increase control over, and to improve, their health. It moves beyond a focus on individual behaviour towards a wide range of social and environmental interventions.

Morbidity - the incidence of disease**:** the rate of illness (as in a specified population or group)

Mortality - the number of deaths in a population or group in a given time or place

Preventable deaths - Avoidable and preventable deaths refers to deaths from conditions that are considered avoidable given timely and effective action including disease prevention and population health initiatives.

Social benefit - The increase in the welfare of a society that is derived from a particular course of action. Some social benefits, such as greater social justice, cannot easily be quantified.

2. Purpose of the report, review method, and rationale

2.1 Purpose

The purpose of this report is to:

- provide an overview of the literature on health co-benefits associated with strategies implemented for climate adaptation and mitigation goals; and
- inform the City of Melbourne about the possible health and social benefits available to the city and its inhabitants from the implementation of measures to put Melbourne on a path to net zero emissions by 2050.

2.2 Method

A desktop review was conducted of the literature on the evidence of health and social co-benefits associated with climate mitigation and adaptation strategies. Relevant literature from 2008-2018 was identified by searching electronic databases and search engines using a range of search terms related to 'climate mitigation' and 'climate adaptation' and 'health co-benefits'. The term co-benefits are sometimes used interchangeably with "additional benefits" or "ancillary benefits" or "win-win-win scenarios", so these search terms were also used. It was supplemented by studies recommended by policy and academic experts in the field. It included peer reviewed studies which described or evaluated health impacts in relation to climate mitigation or adaptation measures or assessed potential health impacts. Studies that considered co-benefits for health associated with active, public and low emissions transport, low carbon diets, energy efficiency in homes and buildings, low emissions energy sources, low carbon healthcare, and green infrastructure, including parks and gardens were also sourced. Studies were included if they were peer reviewed or were considered reputable grey literature from research institutions, governments or non-government organisations. A total of 124 studies were used for the report. The literature was analysed according to themes included in the report contents.

2.3 Rationale

2.3.1 The evidence

The health and social co-benefits of climate mitigation and adaptation strategies can help create additional motivation to take action towards the net zero emissions goal. The evidence reveals economic savings associated with health co-benefits can outweigh the cost of the measures themselves. The literature demonstrates that integrated policies (that consider the implications for a number of sectors and stakeholders) provide opportunities to enhance positive social, environmental and human health outcomes. Importantly, many health co-benefits associated with climate mitigation strategies are realised in short timeframes (days, months and years, depending on the intervention), while the climate benefits accumulate in the longer term (Remais, 2014).

2.3.2 International covenants

The potential for health co-benefits from climate mitigation and adaptation has been recognised in the Intergovernmental Panel on Climate Change Fifth Assessment Report and codified in the UNFCCC Paris Agreement (Smith, 2014; UNFCCC 2015). Health and wellbeing and climate action are also mutually reinforcing and complementary goals in the Sustainable Development Goals (SDGs).

As a party to the Paris Agreement, Australia has an obligation to consider its citizens' right to health in the context of climate policy, and to consider the potential for health co-benefits in climate mitigation strategies. This provides an important framework for sub-national (including local) governments to use to guide decision-making and prioritisation of strategies in their efforts to contribute to the implementation of the Paris Agreement.

2.3.3 Health as a climate change communications 'frame'

Health is an important 'frame'[1] when communicating about climate change: research from the Centre for Climate Change Communication at George Mason University shows when climate change is presented as a health issue, people are much more likely to consider it in a personal context, as an individual threat and something that is understandable and directly relevant to them (Maibach 2010). When the health co-benefits are part of the climate change narrative, this has even more impact – and leads to stronger support for climate mitigation and adaptation strategies (Maibach 2010; Myers, 2012). Importantly, a health frame around climate change communications also has strong appeal across all audience spectrums (ranging from those 'alarmed' about climate change, to those that are 'dismissive'), regardless of political leaning (Myers, 2012). This demonstrates that a health lens provides a way to communicate about climate change in a way that can bypass otherwise partisan and politically hostile debate (Myers, 2012; Bain, 2015).

Research by Sustainability Victoria shows 78% of Victorians are concerned about climate change, with 38% concerned about its impact on health and quality of life (Sustainability Victoria, 2016/17). Insights from psychological science suggest policymakers seeking to improve climate policy outcomes should: emphasise climate change poses current, local and personal risk; and that individuals and the wider community can make a difference; define and communicate social norms (i.e. what others are doing); and highlight what can be gained from immediate action, while linking to valued longer term goals (van der Linden, 2015).

Further, the evidence suggests that personal perception of risk, linked to health, is a powerful influence on behavioural change (Petrovic, 2014).

This points to an important opportunity for the City of Melbourne to use health as a communications vehicle to engage people more deeply in the City's climate change mitigation and adaptation plans, and to use the health co-benefits framing as a positive opportunity and trigger for action.

[1] Frames are 'interpretive storylines' that define why an issue is a problem, who might be responsible, and what can be done (Nisbet, 2009).

3. Introduction and Background

3.1 Risks to health from climate change

Climate change is recognised as a profound threat to the health and wellbeing of people in Australia and around the world, and left unchecked, threatens to undermine the health gains associated with the last 50 years of global development (Watts, 2015). The economic costs associated with the adverse health and social costs of climate change are frequently unrecognised, but are often immense: for example, the costs associated with deaths and injuries, mental stress, worsening chronic illness, domestic violence, and unemployment associated with the 2001 floods in Qld amounted to AUD$7.4 billion. This exceeded the AUD$6.7 billion worth of combined costs of damage to homes, infrastructure, businesses, agricultural production, and the emergency response (Deloitte Access Economics, 2016).

As well as the health costs of climate change, there are significant immediate and costly negative health impacts associated with air pollution - released by the same combustion processes that produce GHG emissions (Watts, 2017; Roy, 2017). Air pollution presents both a personal toll as well as a significant impact on the economy: a 2017 report estimates the present human and economic cost of air pollution in just 41 OECD and BRIICS countries[2] is around 3.2 million deaths and USD$5.1 trillion annually (Roy, 2017). Globally, the World Health Organisation (WHO) estimates 7 million deaths occur each year as a result of exposure to dangerous air pollution (WHO, 2018). As the OECD report shows, this is not just a risk for developing nations: 91% of the world's population lives in places where air quality exceeds the WHO guideline limits (WHO, 2018). It is estimated that the annual death toll from urban air pollution in Australia is 3,000 (AIHW, 2016).

Leading climate change and health researcher Professor Tony McMichael describes climate change as a complex phenomenon which can alter the rate, range and patterns of injury, illness, and death, but emphasises:

"…it is not the climate itself that affects human health; rather, the health consequences result from the environmental, ecological and social impacts of a changing climate." (McMichael, 2011).

The most negative direct impacts on health from climate change include deaths, injuries, and illnesses associated with heatwaves, floods, bushfires and severe storms (McMichael, 2011). Indirect impacts are mediated by environmental or ecosystem factors such as deaths and illnesses related to increases in air pollution, exposure to vector-borne, or food- and water-borne diseases. Further indirect effects arise from: socio-economic and mental health issues associated with trauma and displacement following extreme weather events; poor nutrition associated with declining agricultural production; and exposure to violence and conflict (Workman, 2018). There is an increased risk of cardiovascular and respiratory illness linked with declining air quality and increased aeroallergens associated with climate change (D'Amato, 2013). Indirect risks also include threats to nutritional status associated with impacts on food supply and water security, and threats to personal and community security related to economic instability, migration and conflict (intergroup and interpersonal) (Hsiang, 2013; Butler, 2016).

The extent to which people's health is affected by climate change depends on many factors, including their current health status, age and gender, socio-economic status, and access to social services, infrastructure and support, including healthcare (Smith, 2014). Figure 1 below highlights how climate

[2] Organisation for Economic Cooperation and Development (OECD) and Brazil, Russia, India, Indonesia, China and South Africa (BRIICS)

change impacts on human health as a “threat multiplier” in that it amplifies or increases pre-existing health threats or problems (CDPH, 2018; Kjellstrom, 2013).

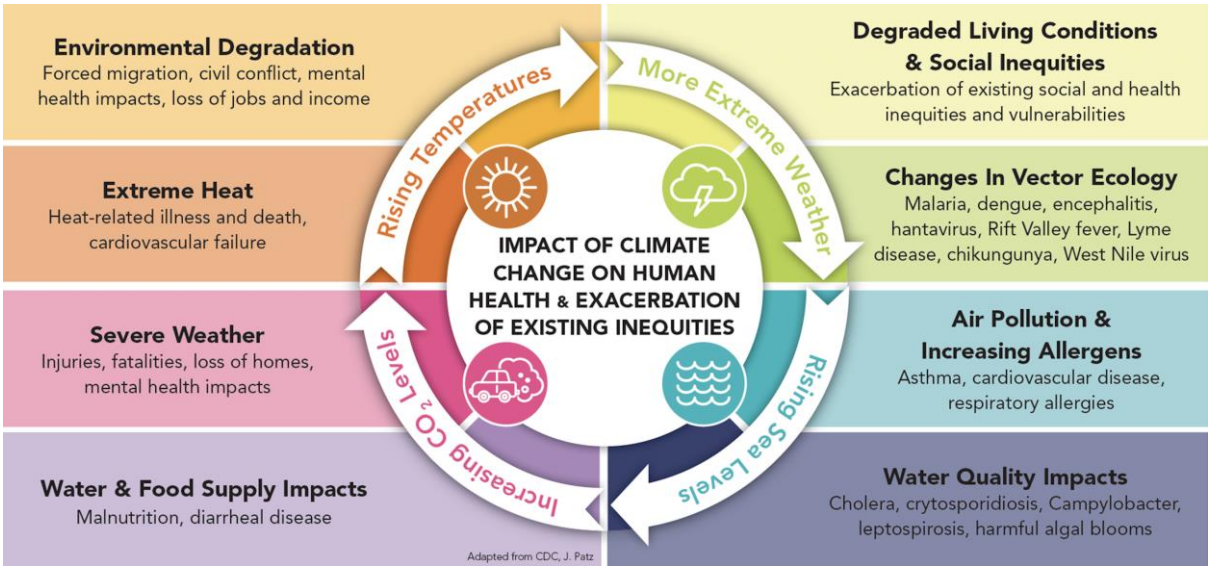

Figure 1: Impact of Climate Change on Human Health and Exacerbation of Existing Inequities (Adapted from CDC, J. Patz by California Department of Public Health).

3.2 Direct impacts: Extreme weather events

Some of the direct risks to health from extreme weather events associated with climate change relevant to the City of Melbourne include heatwaves, floods and storms.

Extreme weather events such as floods, storms, extreme precipitation, droughts, and bushfires are increasing in frequency, duration and intensity (Black, 2015; Lewis, 2014; Steffen, 2017). These put people at risk of injury, illness and death through direct trauma and exposure to air-borne (e.g. smoke haze) and water-borne (e.g. contaminated stormwater) pollutants. Physical displacement, mental health impacts and post-traumatic stress associated with extreme weather all place increased demand on health, emergency and community services (State Government of Victoria, 2009, 2014; Banham, 2018; Curtis, 2017; Mallon, 2013). Extreme events also pose a threat to health services infrastructure, operations and service continuity, as well as to the health workforce, posing further risks to the community if services are inaccessible, unable to function, or not fully staffed (Carthey, 2009).

3.2.1 Heatwaves

Rising global average temperatures are giving rise to more frequent and intense heatwaves (Patrick, 2015). This is exacerbated for city dwellers by the urban heat island event, whereby cities can be 5-11 degrees Celsius hotter than surrounding areas (Patrick, 2015). Heatwaves already cause more deaths in Australia than bushfires, cyclones, earthquakes, floods and severe storms combined (Hughes, 2016). Deaths from heatwaves primarily occur as a result of myocardial infarction (heart attack), respiratory failure, and heat stroke (McMichael, 2011). Socially disadvantaged communities (e.g. those on lower incomes) and people with existing physical (e.g. heart disease, obesity, multiple sclerosis) or mental illness, the very old and the very young, and those living alone are most at risk of negative health impacts from extreme heat (Norton, 2015).

3.2.2 Floods and storms

Severe floods in Australia in recent years highlight that many urban and rural communities are vulnerable to the damaging effects of floods and severe storms. Floods affect health through drownings, injuries, and the spread of disease through contamination of floodwaters with environmental toxins or infectious diseases (Smith, 2014). Severe storms and flash flooding can cause fatalities and injuries, as well as disrupt transport systems, and contribute to power outages (Wales, 2012). Flooding and storms can have serious impacts on mental health, with people whose homes and properties are inundated with flood waters being two to five times more likely to report mental health impacts (psychological distress, anxiety, and depression) than those not flooded (Paranjothy, 2011; Smith, 2014).

3.3 Indirect health impacts: ecosystem-mediated and human institution-mediated risks

Indirect impacts on human health and wellbeing linked to climate change include influences on ecosystems such as increased risk of exposure to infectious and vector borne diseases; food and water borne infections; as well as air pollution and aeroallergens (Smith, 2014; Workman, 2018). Other indirect effects involve health impacts associated with droughts and crop failures, as well social impacts, such as population displacement related to prolonged drought or sea level rise (Smith, 2014).

3.3.1 Air pollution and aeroallergens

Many processes that create GHG emissions also produce local air pollution harmful to human health. Pollutants produced by burning coal, oil and gas for electricity, heat and transport are associated with an elevated risk of heart attacks, strokes, and respiratory diseases, including lung cancer (Smith, 2013). The pollutants abundant in urban air pollution associated with health harms include particulate matter (PM), nitrogen oxide (NOx) and ground level ozone (D'Amato, 2013; Dean, 2018). The City of Melbourne periodically experiences air pollution which poses a serious health risk for residents, workers, and tourists (Cunningham, 2017). A recent report from the Victorian Auditor-General's Office suggests a lack of air monitoring equipment may mean air pollution poses a more serious threat to the people of Melbourne than is currently realised, with exceedances in pollutant concentrations occurring more frequently than EPA reports suggest (VAGO, 2018). Increases in temperatures associated with climate change are also linked to increased production of aeroallergens, which contribute to respiratory problems, such as the severe thunderstorm asthma event in Victoria in 2016 (Tofa, 2017), which caused the deaths of nine people and a massive surge in demand for emergency services and medical care (State of Victoria, 2017a).

3.3.2 Infectious and vector-borne diseases

As temperatures rise, so too does the number, range and resilience of various food-, water-, and vector-borne pathogens (Smith, 2014; AAS, 2015). Food-borne illnesses such as gastroenteritis are caused by bacteria such as campylobacter and salmonella which occur more readily with warmer temperatures (Hall, 2011; Smith, 2014). Given around there are already around 10,000 episodes of gastroenteritis leading to about 80 hospitalisations in Australia every day, more frequent heatwaves will put hundreds more people in Melbourne at risk of food related illness (Voice, 2015). Rising temperatures are also associated with increased exposure to vector-borne diseases, including mosquito-borne viruses such as dengue and Ross River fever. The range of these vectors is expected to increase across Australia under climate change scenarios (Kjellstrom, 2009; Smith, 2014).

3.3.3 Food and water security

Reduced rainfall and drought related to climate change poses a range of risks related to human health and wellbeing. Reduced environmental flows in rivers can lead to declining water quality (Kjellstrom, 2009), loss of aquatic biodiversity, and reductions in available water to support agriculture, threatening food security – all of which have flow on effects for human health (Wales, 2012). Inequitable access to water may exacerbate existing health inequalities, while declining water availability may impact water quality and reduce crop yields, leading to higher food prices and limiting food options (Hanjra, 2010).

3.3.4 Mental illness and stress

Environmental and climatic changes contribute to a diverse range of mental health impacts. These include mental stress related to economic and emotional pressures associated with increasingly frequent and severe climate change-related disasters, including droughts (Hanigan, 2012; Climate Institute, 2011). An emerging mental health risk is a sense of despair and hopelessness related to inadequate societal responses to the threat of climate change (Hayes, 2018). Other impacts include exacerbations of psychiatric disorders during heatwaves (Hanse, 2008). Research reveals worry and distress about the future in relation to climate change, and anxiety and depression related to inaction, constitutes both a negative health impact, as well as a basis for action (Berry, 2018).

3.3.5 Occupational health risks

In addition to the adverse effects of heat waves, hotter temperatures also pose occupational health and safety risks (Varghese, 2018). The sheer volume of workers entering the City of Melbourne during weekdays increases the local air temperature in the city (Klein, 2017). Hotter temperatures associated with climate change can pose serious occupational risks, particularly for outdoor workers, and those working in indoor noncooled environments (Hanna, 2011; Singh, 2013), such as manufacturing, bakeries, laundries, and restaurant kitchens (Varghese, 2018). Occupational heat stress is associated with an increase in workplace injuries, with hot conditions contributing to discomfort, fatigue, and reduced concentration and alertness (Varghese, 2018). Reduced work capacity related to occupational heat stress carries a significant economic toll and is already associated with lost productivity costing $6.2 billion per annum in Australia (Zander, 2015).

3.3.6 Damage and displacement

Sea level rise and drought both pose threats to the population in Victoria and have implications for the City of Melbourne (Wales, 2012). Several coastal municipalities are at risk of inundation associated with sea level rise, posing risks to property and associated economic and social costs (Warren-Myers, 2018; Wales, 2012). Forced displacement from homes and properties in low lying and coastal communities in the face of inundation associated with sea level rise, and from regional communities in the context of persistent drought, will bring a range of health challenges in the future, including psycho-social ill-health (Schwertle, 2017).

4. Health co-benefits associated with climate change interventions

The good news is that there are many health co-benefits associated with strategies that reduce GHG emissions. Provided these strategies are developed with the potential health benefits (and risks) in mind, they offer enormous potential to improve the general health and wellbeing of the population, as well as to provide economic benefits, since the cost savings from avoided ill-health and productivity gains often exceed the costs of policy implementation (Watts, 2017; Thompson, 2014; Landrigan, 2018).

Co-benefits (or 'ancillary benefits' as they are sometimes known) refer to the additional benefits that accrue from actions or strategies designed or implemented for a different purpose. This report provides an overview of the literature in relation to health co-benefits (improvements in health outcomes, or reductions in health risks) associated with climate adaptation or mitigation measures designed to reduce greenhouse emissions or to limit other risks associated with climate change. These offer a win-win scenario – both reducing emissions and delivering health benefits. Carefully designed strategies can deliver a triple win as they can also deliver (often substantial) economic savings.

Health co-benefits arising from climate adaptation and climate mitigation strategies can often help address existing health challenges, such as preventable lifestyle diseases (cardiovascular disease, obesity, Type 2 diabetes), as well as respiratory diseases linked to air pollution (asthma, lung cancer), and mental health (stress, anxiety and depression). Health and social benefits also arise when climate strategies positively impact on the social determinants of health – those wider forces that shape the conditions of daily life – economic factors, social and environmental conditions, education, cultural influences, gender equity and personal autonomy.

While there remains some uncertainty about the longer-term climate outcomes in relation to climate change mitigation and adaptation actions, there is a high level of certainty in relation to the health co-benefits that accompany them and the time frame within which they can be realised (Workman, 2018).

The co-benefits approach offers enormous advocacy potential as it positions climate action in the context of the positive outcomes that can be realised locally, and in the short term, while the climate benefits accumulate over a longer time scale. It provides the opportunity to elevate particular policy goals higher on the political agenda as the positive co-benefits 'story' can help overcome political opposition and increase policy acceptability in the community (Mayrhofer, 2016).

Health is already a key message in climate advocacy campaigns, as many health and environmental advocates recognise both the threat to health and the opportunity to positively engage communities associated with integrating climate change and health strategies and communications (EJA, 2017; ACF, 2018; PHAA, 2014).

4.1 Climate mitigation and adaptation strategies with health co-benefits

This review provides insights into the potential health co-benefits and positive social benefits accompanying economic savings associated with integrated climate change and health policies.

The evidence reveals that there are significant health co-benefits associated with climate adaptation and mitigation policies in relation to transport, buildings, energy, food, green infrastructure and healthcare.

These benefits arise from adaptation and mitigation actions which reduce or help avoid adverse health impacts and provide a strong rationale and motivation, in addition to the climate benefits, for the net zero emissions goal.

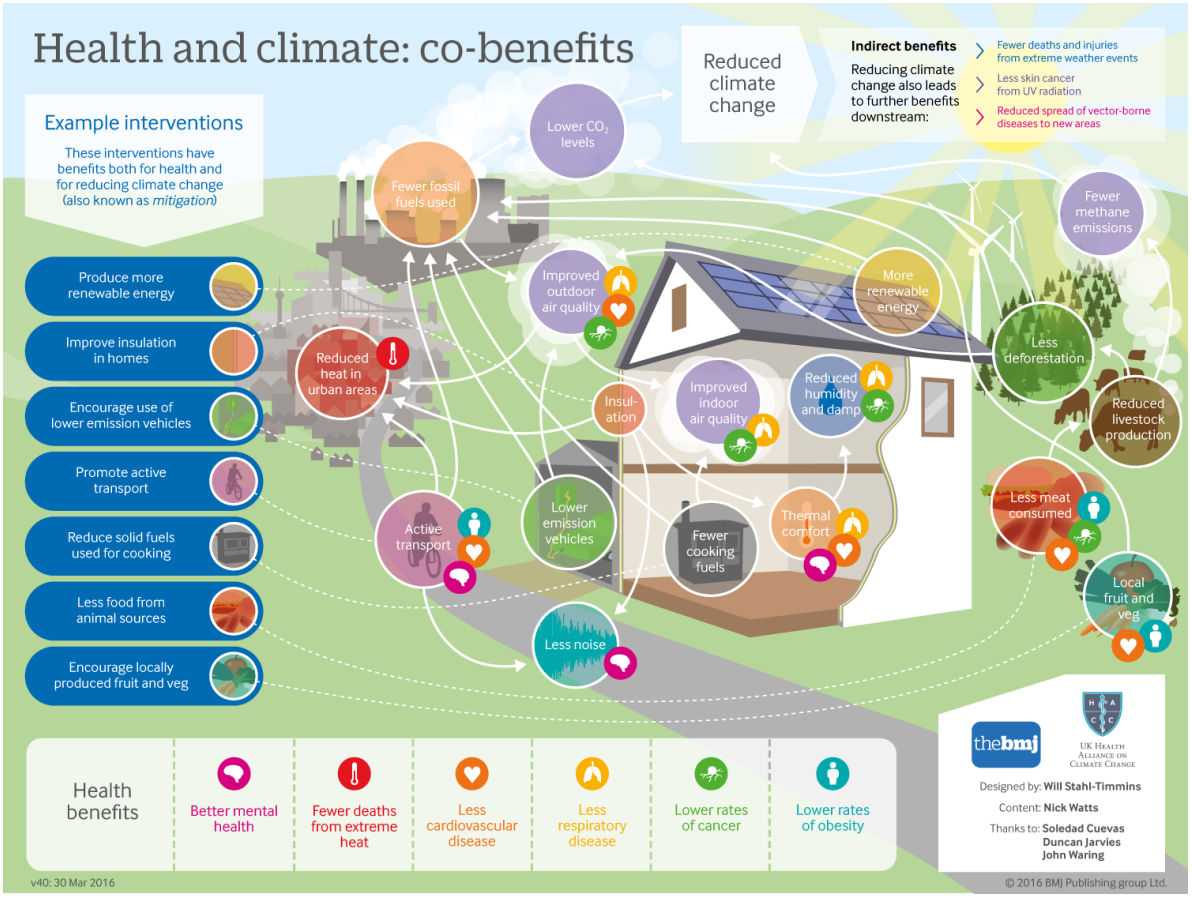

Figure 2: Health and climate: co-benefits, British Medical Journal, 2016

Table 1. Summary of key health co-benefits across sectors

Sector	Mitigation or adaptation initiative	Key health co-benefits
Transport	Increased active / public transport; replacement of diesel/petrol vehicles with clean-powered electric vehicles	Reduced prevalence of cardiovascular and respiratory illness, type 2 diabetes, dementia and cancer
Buildings	Improving energy efficiency in buildings, improved insultation and natural ventilation; designing for physical activity and social interaction	Reduced risk of heart disease, strokes, injuries, asthma and other respiratory diseases; improved mental health and psychological well-being; reduced visits to GPs, fewer hospitalisations and days off work or school
Energy	Substituting fossil fuels with renewable energy for electricity and transport	Potential for thousands of avoided premature deaths nationally, substantial savings for healthcare budgets
Food	Increasing proportion of plant-based products in diets; local food production; avoiding overconsumption	Reduced ischaemic heart disease, obesity and bowel cancer; improved community resilience, improved psychological wellbeing
Green infrastructure	Increased urban tree canopy, parks and gardens, green roofs	Reduced respiratory disease (from improved air quality); better overall health, reduced stress, and an enhanced sense of personal wellbeing; reduced heat stress; positive mental health
Healthcare	Reducing healthcare waste through recycling and low carbon procurement; improved energy efficiency; encouraging active transport / clean power vehicles; delivering healthcare at home; investing in renewable energy	Reduced environmental pollutants; improved air quality; reduced morbidity and mortality; improved physical and mental health; reduced healthcare costs

Sources: Jarratt, 2012; Remais, 2014; Chapman, 2088, Milner, 2012; WHO, 2011; Urge-Vorsatz, 2012; Buonocore, 2015; Thompson, 2014; Okvat; 2011; Patrick, 2015; Friel, 2013; Haines, 2010; Demuzere, 2014; Bowen, 2015; Townsend, 2010; Sarajevs, 2011; Tallis, 2011; Eckelman, 2016; Pencheon, 2009; McGain, 2010; Naylor, 2012, Sherman, 2016.

4.1.1 Transport

In Australia, the transport sector accounts for 16% of total GHG emissions, of which 10% comes from light vehicles (Climate Change Authority, 2018). In addition to GHGs, the combustion of fossil fuels for transport also produces harmful local air pollutants, the annual health costs of which has been estimated at USD$5.8 billion in Australia (OECD, 2014).

A number of international studies have investigated the health benefits associated with climate change strategies involving urban transport. Strategies to expand and promote public transport offer a range of health co-benefits associated with a reduction in air pollution, traffic injuries, noise, congestion and physical activity (Kwan, 2016).

Further, strategies to reduce emissions from transport frequently lead to improvements in air quality, due to reduced cardiovascular and respiratory disease (eg heart attacks, strokes, asthma, lung cancer) (IARC, 2013; Remais, 2014) and reduced hospitalization and emergency room visits for cardiovascular and respiratory diseases (McKinley, 2005). The increased physical activity associated with expanded public transport options can also reduce premature mortality (early deaths) and morbidity (illnesses) (McKinley, 2005). More stringent air quality guidelines for cities in Australia would lead to significant co-benefits and therefore more stringent mitigation targets could deliver significant health and economic co-benefits (Dean, 2018).

4.1.1.1 Active transport offers lower emissions and improved health

A study which modelled four different transport policy scenarios in European cities (Creutzig, 2012) found synergistic health and social gains and significant emissions reductions are possible if city infrastructure is adapted for pedestrians, cyclists, and efficient public transport. In larger cities (> one million people), increasing the modal share of public transport to beyond 50% offers the most viable option for health and climate gains, while smaller cities (where shorter trips are possible) can achieve emissions reductions through a modal shift to more than 50% walking and cycling (Creutzig, 2012). The nature of the surrounding built environment (i.e. whether or not it is conducive to walking), access to transit stations, and local culture and climate influence people's willingness to walk to catch public transport (Kwan, 2016).

Comprehensive policy packages that combine 'push' (pricing disincentives for cars, infrastructure changes to discourage traffic), and 'pull' factors (encouraging public transport, increasing active transport infrastructure), along with fuel efficiency standards and urban planning levers offer the biggest health co-benefits and emissions savings, according to Creutzig (2012). This is supported by a systematic review of the literature by Quam (2017), which reinforces that a combination of initiatives to increase public and active transport and cleaner operating vehicles offers the best opportunities to reduce GHG emissions and achieve positive health outcomes.

Active transport options also help address the health burden of preventable chronic illnesses associated with sedentary lifestyles (Larouche, 2012). A 2010 study of the potential effect of increased walking and cycling in urban areas in England and Wales found reductions in the prevalence of type 2 diabetes, dementia, ischaemic heart disease, cerebrovascular disease, and cancer related to increased physical activity (Jarrett, 2012). These health improvements were estimated to deliver savings of UK£17 billion within 20 years for the National Health Service – funds that could either reduce pressure on healthcare budgets or be made available to fund additional health services (Jarrett, 2012). A study from New Zealand found that shifting just 5% of shorter trips in urban settings (<7km) from car to bicycles would save around NZD$37 million in fuel bills, avert 50,000 tonnes of carbon dioxide (CO_2), and deliver positive health effects worth NZD$200 million per annum (Lindsay, 2011).

A US study further emphasises the triple health, climate and economic benefits of substituting short car trips with walking and cycling – revealing the associated reductions in air pollution and increase in physical activity would deliver cost savings of USD$7 billion per annum (in a population of around 30 million people), and amount to 1,769Mt of CO_2 avoided each year (Grabow, 2012).

In addition to the physical health benefits, active transport options also offer psychological benefits - from increased physical activity, reduced noise, increased social interaction, and exposure to green spaces (Wolkinger, 2017).

4.1.1.2 Comprehensive policies deliver economic savings

Economic and health modelling by Wolkinger (2017) on the implementation of ambitious transport policies (restricted car use, active transport and introduction of electric vehicles) in three cities in Austria found huge savings from avoided ill health and productivity gains, suggesting benefits arising from these policies in just these three cities would deliver economic savings equivalent to 0.25% of overall Austrian gross domestic product (GDP).

This study found the biggest opportunities for emissions cuts and health gains from switching to electric vehicles, powered by carbon neutral sources (Wolkinger, 2017). The corresponding decline in air pollution (principally NO_2 and PM) would mean fewer heart attacks and incidences of lung cancer, fewer hospital admissions, and improved productivity associated with less work time lost to illness (Wolkinger, 2017).

Other studies suggest transport scenarios that combine a number of elements of 'green' or low carbon transport options (e.g. cleaner operating vehicles alongside increased public and active modes of transport) deliver the greatest health benefit (Quam, 2017).

Proposed policy mechanisms to realise both GHG emissions reductions and health co-benefits associated with transport include: financial disincentives to correct the currently externalised health and social costs of current transport options; initiatives to engage communities in identifying and choosing alternatives; and programs to encourage active transport and modal shifts (Quam, 2017).

Despite these documented benefits, many government and local authorities are not investing in quantitative analysis of the health co-benefits associated with measures to simultaneously tackle air pollution and GHG emissions (McKinley, 2005).

Closer analysis of these benefits in the City of Melbourne may well reveal, as in other cities in developed nations, that the health and climate benefits associated with measures to improve air quality and reduce emissions significantly outweigh the costs of implementing adaptation and mitigation strategies.

4.1.2 Buildings

Improving the energy efficiency of homes and buildings can deliver important health benefits as well as financial savings from reduced energy consumption, while reducing GHG emissions (WHO, 2011).

Improving energy efficiency in buildings can deliver positive health benefits by creating more stable indoor temperatures, improving air quality, reducing energy use and costs, and ease cost of living pressures (Milner, 2012). These health benefits can manifest in a variety of ways, such as reduced visits to GPs, fewer hospitalisations and days of work or school each of which benefit both individuals and the broader community (Chapman, 2008).

Measures that reduce fluctuations in heat and cold, improve natural ventilation and provide greater energy efficiency can reduce the risk of heart disease, strokes, injuries, asthma and other respiratory diseases (Milner, 2012; WHO, 2011). There is also good evidence that homes that are well-insulated improve mental health and psychological wellbeing (Milner, 2012).

4.1.2.1 Better health, lower emissions and lower costs

An analysis of health gains, energy and emissions savings and cost savings by retrofitting homes in New Zealand found the total savings associated with avoided ill health and energy savings were 1.5-2 times the cost of implementing the initiative (Chapman, 2008). A modelling study in the US which estimated the energy savings and health benefits of retrofitting 46 million single family homes with insulation found the health benefits of the initiative would save USD$1.3 billion each year, while the energy savings were worth USD$5.9 billion per annum (Levy, 2003).

Designing homes and buildings that utilise sustainable, recycled and local materials can reduce the carbon footprint, while reducing health risks associated with climate change (Urge-Vorsatz, 2012). Access to energy efficiency measures for low income households is a health protection measure as affordability of essential services is an important social determinant of health (ACOSS, 2017).

The use of state-of-the-art design and technology to build new, and retrofit old homes, can substantially reduce the risks of energy poverty for low income households, even in jurisdictions with high energy use (Urge-Vorsatz, 2012). It is estimated heating and cooling costs in developed nations could be reduced by 66-75% by 2050 (and accrue economic savings four times the cost of implementation) if new and existing buildings adopted passive house energy standards (<15kWh per sqm per annum) (Urge-Vorsatz, 2012).

4.1.2.2 Well-designed low carbon buildings can encourage positive health and social behaviours

The characteristics of the built environment can also influence social behaviours and positively impact on health. A study exploring the links between green infrastructure and buildings and social behaviour concluded that increased greenness and natural elements around a building reduced crime levels in the area, as well as aggression and violence levels of residents (Kuo and Sullivan 2001a, 2001b in Townsend, 2010). Building and infrastructure design features which promote social engagement and physical activity, such as wide, well lit, easily accessible stairs, as well as walking paths and gathering spots, can encourage low carbon behaviour and contribute to positive physical and mental health outcomes (WHO, 2011; Urge-Vorsatz, 2012).

There is a potential risk of unintended adverse health consequences associated with improving energy efficiency through reducing air leaks, as the reduced air flow may lead to an increase in indoor air pollution (from tobacco, particles, radon, volatile organic compounds), so it is important that planned upgrades involve collaboration between agencies, public health experts, and affected households to avoid unintended adverse health consequences and ensure optimal outcomes (USEPA, 2017).

There are substantial opportunities to simultaneously achieve emissions reductions and promote public health and wellbeing, as well as social cohesion in the City of Melbourne through strategies to improve the energy performance of buildings, through design of built infrastructure, and inclusion of green infrastructure requirements in urban design.

4.1.3 Energy

The literature on emissions reductions in the electricity sector inevitably overlaps and intersects with those in other sectors, given the contribution of carbon intensive energy sources to GHG emissions in transport, buildings and food, as well as healthcare.

There is considerable consistency across studies from different nations in relation to the substantial co-benefits associated with climate change mitigation strategies that shift energy production away from fossil fuels and towards renewable energy sources (Balbus, 2014). These co-benefits include thousands of avoided premature deaths and amount to tens of billions of dollars saved for economy-wide initiatives in nations such as the US (Balbus, 2014; Thompson, 2014). These benefits translate to between USD$40 and USD$198 per tonne of CO_2 equivalent avoided (Balbus, 2014; Nemet, 2010).

4.1.3.1 Cutting emissions from energy is a win-win-win option

Generally, the evidence demonstrates that the value of the health co-benefits arising from emissions reductions in the energy sector exceed the costs of energy policy implementation. In some cases, the value of these savings is immense. For example, a study from researchers at the Massachusetts Institute of Technology in 2014 found monetised human health benefits associated with air quality improvements from various policy scenarios could offset 26–1,050% of the cost of the policies (Thompson, 2014).

The biggest co-benefits demonstrated in this study were associated with a national cap and trade scheme. However, scenarios involving clean energy standards and transportation policies also delivered cost savings. The findings are considered conservative, as they reflected health improvements related to air quality only and did not include health gains available from other potential parallel strategies (e.g. transport policies which encourage walking and bicycling).

The researchers conclude that: *"cost-benefit analyses of climate policy that omit regional air pollution could greatly underestimate benefits"* (Thompson, 2014).

Buonocore (2015) also found the displacement of fossil fuel powered electricity generation by renewable energy and energy efficiency delivers both climate and public health benefits. These benefits vary according to the type of generation displaced, its location and the distribution of the population proximal to energy generation infrastructure (i.e. power plants). A comparison of four different renewable energy / energy efficiency installations across six locations in the US found benefits ranging from USD$14-$170 per MWh. The benefits were greatest where coal was displaced, with solar photovoltaics, wind and energy efficiency delivering health benefits at comparable prices (Buonocore, 2015).

It is important to note, however, that strategies to reduce emissions in the energy sector do not always in and of themselves deliver health co-benefits. For example, subjecting coal-fired power plants to CO_2 emissions limits without including restrictions on sulphur dioxide and nitrogen oxide emissions would reduce the available health co-benefits and limit near term gains (Balbus, 2014). For this reason, it is vital that climate mitigation strategies in the energy sector (as in other sectors) include an evaluation of the associated health impacts in order to ensure emissions reductions also deliver health benefits.

Strategies to encourage energy efficiency and further uptake of renewable energy systems will contribute to emissions reductions for the City of Melbourne and reduce healthcare costs arising from the burden of disease related to fossil fuel combustion in the region. Decarbonising the energy sector will also provide the platform for low emissions transport through the adoption of electric vehicles powered by renewable energy.

4.1.4 Food

One of the highest emitting parts of the food system is associated with the raising of livestock for meat production (Friel, 2013). Since many people in OECD nations, including Australia, consume more meat and protein than is recommended in dietary guidelines, reduction in meat consumption can deliver both climate and health benefits (Friel 2013). Lowering consumption of animal products in the population reduces consumption of saturated fat, which can reduce the risk of ischaemic heart disease, as well as reduce household and societal expenditure (Haines, 2010).

A 2009 study in *The Lancet* found reducing consumption of animal products by 30% would reduce the incidence of ischaemic heart disease by 15% (Friel, 2009). While consumption of red meat in Australia is declining (80g/day in 2016 compared to 100g of red meat /day in 2010) it is still above the recommended average of 50g/day (ABS, 2016; Friel, 2010). In 2010, it was estimated that reducing this to 50g/day would reduce emissions from livestock in Australia by 22% and reduce the incidence of colorectal cancer by 11% (Friel, 2010).

4.1.4.1 A healthy, low carbon diet involves whole food, mostly plants

An Australian case study (Friel, 2013) demonstrates it is possible to reduce household emissions related to food consumption and achieve a healthy, nutritionally balanced diet. This can be achieved through replacing typically consumed foods with readily available alternatives with lower emissions and a lower environmental footprint. This approach is based on three principles: avoiding food above any person's individual energy requirement (i.e. avoiding overeating); avoiding energy dense, highly processed and packaged food; and choosing more plant-derived foods and less animal products (Friel, 2013).

While low carbon diets typically emphasise reducing or eliminating consumption of animal products, studies from the UK have found a low emissions diet which meets dietary requirements for good health can be achieved without omitting meat and dairy and without increasing costs to consumers (Macdiarmid, 2012).

Modelling of the health impacts of low carbon diets in the UK suggests a 50% reduction in meat and dairy products (from 2005 levels), replaced with fruit, vegetables and cereals, would deliver a 19% reduction in GHG emissions and a 42% reduction in land use while averting or delaying between 30,192 and 43,592 deaths each year in the UK (Scarborough, 2012).

A comprehensive review of the literature on the impacts of adopting a sustainable diet[3] on GHG emissions, land use, water use, and health (Aleksandrowicz, 2016) found that adopting a sustainable diet would deliver GHG emissions reductions of 70-80%, along with a 50% decline in water use, with modest health gains from reductions in mortality rates and risk.

Achieving dual benefits in terms of emissions reductions and health gains in relation to diet requires a comprehensive understanding of diet and health interactions, cultural traditions and available food sources (Quam, 2017).

The best outcomes for both health and climate can be achieved by identifying diets that are safe, healthy and nutritious as well as low carbon, and also support healthy ecosystems, encourage

[3] The United Nations Food and Agriculture Organization (FAO) defines sustainable diets as those which are healthy, have a low environmental impact, are affordable, and culturally acceptable.

biodiversity, as well as being affordable, culturally appropriate, and use natural and human resources in a fair and sustainable manner (Quam, 2017).

4.1.4.2 Dual benefits of growing local food

Localised food systems not only help reduce 'food miles' (and therefore emissions) but can also contribute to social benefits through addressing economic inequity (through access to affordable food) and contributing to social capital and health co-benefits (Okvat; 2011; Patrick, 2015). Community gardens promote social interaction thereby reducing social isolation and improving mental health, as well as offering physical health benefits through physical activity, and reducing the risks of morbidity and mortality associated with preventable chronic illnesses (Townsend, 2011; Okvat, 2011).

Possible policy options to encourage healthy low carbon diets include taxing unhealthy or high carbon food choices. However, this should be accompanied by community education programs and revised dietary guidelines to ensure substituted foods are also nutritious and contribute to a balanced diet (Aleksandrowicz, 2016; Quam, 2017). Improvements in diet and exercise will contribute to a healthier population, which is likely to result in reduced hospital admissions, and reduced health costs as well as reduced GHG emissions from the health sector (Quam, 2017).

Programs to encourage the adoption of a low carbon diet and local urban food systems and food production, including the use of community gardens, can help reduce emissions in the City of Melbourne, and boost individual and population health, while contributing to social cohesion and community resilience.

4.1.5 Green infrastructure, including parks and gardens

There is good evidence that 'green' infrastructure (parks and gardens, green roofs and facades, tree canopy) in urban settings can make an important contribution to climate mitigation and adaptation efforts as well as confer human health benefits (Demuzere, 2014; Bowen, 2015).

Green urban infrastructure is associated with climate mitigation (by providing CO_2 sequestration), supporting climate resilience (by helping to mitigate the effects of extreme weather i.e. floods, heatwaves and extreme rainfall) as well as physical and psychological health benefits (Demuzere, 2014).

Access to parks and gardens is associated with increased physical activity, better overall health, reduced stress, and an enhanced sense of personal wellbeing (Demuzere, 2014; Townsend, 2010). By providing opportunities to interact with nature, engage in physical activity, and reduce stress, increasing access to green infrastructure in urban environments has a positive effect on physical, mental and social health (Bowen, 2015).

4.1.5.1 Nature: our air filter

Trees and urban forests, along with domestic gardens, reduce air pollution, help reduce the urban heat island effect, improve thermal comfort and limit heat stress for people as well as other species (Demuzere, 2014; Norton, 2015). Vegetation helps absorb local air pollutants, such as ground level ozone and NOx, and helps remove PM, such as dust, ash, pollen and smoke (Sarajevs, 2011; Tallis, 2011). Studies from the UK reveal increasing tree cover by 10% in the Great London area could remove between 1,000-2,000 tonnes of PM_{10} by 2050, or almost 3% of PM_{10} pollution (Tallis, 2011).

Choosing plant species to include in urban green infrastructure to realise climate and health benefits should be informed by local climate conditions, as well as community values, and should seek to avoid

unintended negative health impacts, such as aeroallergens from increased pollen production associated with certain species (Norton, 2015; Cheng, 2013).

4.1.5.2 Green = cool = comfort

Green roofs reflect sunlight, creating cooler conditions which reduce energy use, and provide insulation (Demuzere, 2014). Green roofs can cool at neighbourhood scale if they cover a large area of low buildings (Norton, 2015), and may deliver cooling of up to three degrees Celsius (Santomouris, 2014). The combination of green roofs and green walls is demonstrated to have a substantial effect on mitigating high temperatures in urban environments, with the potential to achieve energy savings from cooling buildings between 32% and 100% (Alexandri, 2008). Parks and gardens also offer a cooling effect; a London study found Kensington Gardens provided cooling of 4 degrees Celsius up to 440 metres beyond its boundary (Doick, 2014).

Heat-related deaths and illnesses associated with the urban heat island effect can be minimised by the cooling that plants provide through shade and evapotranspiration (the release of water vapour from plants to the surrounding air) (Berry, 2013, Zkang, 2014).

Community gardens offer the potential for emissions reductions through carbon sequestration, reduced emissions from transporting food, reductions in methane (if food waste is used as compost), and through the contribution of vegetation to urban cooling, reducing energy demand, and therefore emissions (from fossil fuel-based power sources) (Okvat, 2011).

Community food gardens can also enhance food security, as well as support positive social relationships, enhance people's capacity to cope with stress, and foster environmental stewardship (Demuzere, 2014; Townsend, 2010). Public participation in the management of green spaces, such as parks and watershed restoration, can boost individual self-efficacy, which is important for positive mental health, as well as civic participation (Demuzere, 2014).

4.1.5.3 Access to nature as a health protection measure

The health benefits associated with green infrastructure also carry significant economic benefits (Bowen, 2015). Access to parks and recreational facilities (because of the physical activity it facilitates) in just 11 cities in the US has been estimated to save between USD$4 million to USD$90 million in healthcare budgets each year, while increasing green space across the Netherlands by 10% has been estimated to save €65 million in annual healthcare costs (Bowen, 2015).

Increasing the natural environment and green spaces in the City of Melbourne offers the opportunity to reduce emissions through carbon sequestration and reduced energy demand, while delivering important health benefits through improved air quality, reduced heat stress, as well as enhanced psychological and social wellbeing and resilience.

4.1.6 Healthcare

The health sector is itself a considerable contributor to GHG emissions production: in Australia it is responsible for 7% of total national emissions (Malik, 2018). Hospitals and health services also produce substantial quantities of local environmental pollutants, including air pollution, which contributes to the burden of illness and deaths in the community (Eckelman, 2016). Reducing health sector emissions would also reduce healthcare expenditure and contribute to improved public health (Eckelman, 2016). Investing in health promotion and illness prevention programs canl help reduce health costs as well as reduce GHG emissions from the health sector (Quam, 2017).

Hospitals are high energy users, and produce considerable quantities of waste, much of which could be reduced through improved waste segregation, recycling and procurement decisions (Naylor, 2012). The size of the healthcare workforce, and the 24-hour nature of its operations, contribute to a large carbon footprint from transport to and from healthcare services (Holmer, 2012). The bulk of healthcare emissions however occur upstream in the healthcare supply chain, particularly in the manufacture and distribution of medicines (NHS, 2008). It is often assumed that a high carbon and environmental footprint is necessary for the provision of quality healthcare (MacNeill, 2017), however there are many opportunities to reduce emissions across a range of areas in this complex sector.

Some specific opportunities include:

- reducing energy use (from heating, cooling, and ventilation);
- reducing emissions from transport (for staff, patients and visitors);
- improving energy performance of buildings (through insulation and lighting sensors);
- assessing the carbon footprint of healthcare procedures and interventions, avoiding unnecessary tests, treatments and procedures, and avoiding unnecessary travel (i.e. using telehealth, webconferencing);
- implementing sustainable procurement practices (requiring carbon disclosure in all buying, and commissioning and contracting decisions);
- avoiding single use and disposable products where possible;
- reducing pharmaceutical waste; and
- substituting anaesthetic gases with a high global-warming potential (GWP) with safe, effective alternatives (Pencheon, 2009; McGain, 2010; Naylor, 2012; Sherman, 2016).

Initiatives that promote active travel and public transport options among healthcare workers deliver personal health benefits from more physical activity, as well as reduced traffic congestion and air pollution (Naylor, 2012; Pencheon, 2009). Delivering healthcare closer to home or at home can substantially reduce emissions, reduce the cost of healthcare and improve the experience for patients (e.g. less disruption, and alienation from family and home, and greater comfort) as well as deliver positive health outcomes (Pencheon, 2009). Greater utilisation of e-health options, such as consultations via videoconference, and use of e-health diagnostic and prescribing systems can reduce travel and emissions in the sector (Holmer, 2012).

The health promotion and health risk prevention responsibilities of the health sector and the health professions offer a unique and important role in climate change mitigation (McMichael, 2011). A key element of this, as described by Professor Tony McMichael, involves health professionals:

> *"promoting the positive message that many mitigation strategies will also yield additional, near-term, health gains to any local population that takes such action".*

The health sector in Australia and around the world is increasingly recognising the imperative to reduce GHG emissions and build climate resilience in ways that improve public and environmental health (GGHH, 2018).

Strategies to reduce emissions in healthcare in Australia and internationally which also confer immediate and local health co-benefits for individuals and the wider community to date have included:

- Transport access guides to highlight pathways and opportunities for active and public transport options (Pencheon, 2009);
- Developing cycling maps to highlight routes to and from health facilities (Health Promotion Service, 2009);

- Working with local councils develop to Bicycle Plans (Daley, 2007); offering cycling proficiency courses, and establishing a staff bicycling pool (Rissel, 2009);
- Implementing energy efficiency measures e.g. lighting upgrades, energy management controls, education programs (UnitingCare, 2016; Southern Cross Care, 2016);
- Increasing recycling and reducing waste to landfill (Royal Melbourne Hospital, 2017);
- Investing in renewable energy to offset emissions from health services (Gundersen Health System, 2016); and
- Using heat reflective paint to reduce heat load in buildings by 5-15 degrees Celsius (Kooweerup Regional Health Service, 2017).

Due to its size and the complex nature of healthcare operations, achieving net zero emissions in the health sector in Melbourne will require the concerted efforts of many actors. Evidence from existing networks demonstrates that collaboration and information sharing through a community of practice can help promote innovation, provide motivation, and accelerate the adoption of emission reduction strategies in healthcare (GGHH, 2018).

Evaluation of healthcare's carbon footprint at the facility level in the City of Melbourne would allow for more targeted interventions to reduce emissions, particularly if it involves engagement of a cross section of stakeholders, including, but not limited to, hospital executives, facilities managers, engineers, clinicians, sustainability officers, and consumers.

Engagement of healthcare facilities and the health workforce in the City of Melbourne in the further development and implementation of the net zero emissions plan will be key to ensuring healthcare facilities are on track to help deliver this goal. The use of health messages (and health messengers) will be critical to engaging the wider community and communicating the human and social benefits of emissions reductions.

5. Implications and opportunities for City of Melbourne

The evidence presented here suggests there is potentially substantial health co-benefits and positive social impacts available to the people in the City of Melbourne from climate adaptation and mitigation strategies to reduce emissions. These benefits are available to the council staff, as well as residents, visitors, workers, and business owners in the city.

Health co-benefits are available from low and net zero carbon strategies across transport, buildings, food, energy, green infrastructure and healthcare. The implementation of climate mitigation and adaptation strategies across these sectors can reduce the burden of disease in the community, deliver economic savings which strengthen the local economy, and help protect the community from the impacts of climate change.

A brief summary of the opportunities in each of these sectors is presented here:

Transport: Strategies that aim to reduce emissions from transport appear to be best approached as a package of policy measures in order to realise the maximum health and social benefits as well as emissions reductions. This may include a combination of policies that: discourage car use to reduce congestion and improve air quality, as well as expand the infrastructure for, and encourage the use of, public and active transport options.

Buildings: Encouraging investment in energy efficiency measures for homes and buildings can deliver substantial and cost-effective emissions reductions, while promoting physical and psychological wellbeing and improving personal comfort, while also reducing energy costs and therefore economic pressures (itself a contributor to positive health and social outcomes).

Energy: Strategies to encourage the purchase - and where possible, the generation - of renewable energy, along with promotion of fuel switching and energy efficiency in the City of Melbourne can reduce operating costs for businesses and services, contributing to economic productivity and job creation. With prices for solar energy continuing to decline, inclusion of solar power on the majority of buildings can assist in ensuring equitable access to electricity, as well as help maintain thermal comfort while ensuring ongoing affordability.

Food: There is sufficient evidence to include strategies to promote a low carbon diet into the City's policy suite, with potential to address significant existing health burdens and healthcare costs in the population, particularly in relation to obesity, diabetes, and heart disease. The studies cited here contribute to the body of evidence on which to base the inclusion of environmental criteria into dietary guidelines.

Green infrastructure: Expanding the City's green infrastructure offers the opportunity to reduce the urban heat island effect (and therefore heat stress), reduce energy consumption, improve air quality, improve physical, psychological and mental health and wellbeing, as well as contribute to enhanced social capital.

Healthcare: As a significant contributor to emissions, strategies to reduce emissions in the health sector must form a key element of the City of Melbourne net zero emissions strategy. Health professionals, once engaged, can be powerful agents for change in relation to climate mitigation and adaptation in the health sector, and should be brought into policy discussions early and often to obtain access to their expertise and enhance their capacity as positive agents of change.

6. Recommendations and Conclusion

6.1 Key recommendations:

1. The City of Melbourne is encouraged to use health as a communications vehicle to engage people more deeply in the City's climate change mitigation and adaptation plans, and to use the climate-health co-benefits framing as a positive opportunity and trigger for action.
2. Closer analysis of the health and climate benefits associated with measures to improve air quality and reduce emissions in the City of Melbourne should be undertaken as a priority, as the evidence suggests the savings associated with avoided ill-health and productivity gains may well outweigh the costs of implementing adaptation and mitigation strategies.
3. More stringent air quality guidelines deliver significant health and economic co-benefits. Given the demonstrable benefits of linking emissions reductions and health goals in relation to improved air quality, this should be a central focus in the city's net zero emissions goal.
4. Investing in through strategies to improve the energy performance of buildings, through design of built infrastructure, and inclusion of green infrastructure requirements in urban design offers substantial opportunities to simultaneously achieve emissions reductions and promote public health and wellbeing, as well as social cohesion, in the City of Melbourne**.**
5. Initiatives to encourage energy efficiency and decarbonising the energy sector to facilitate clean and healthy electricity and transport options should be central to the City of Melbourne net zero emissions strategy.
6. Programs to encourage the adoption of a low carbon diet and local urban food systems and food production, including the use of community gardens, should be part of the City of Melbourne net zero emissions strategy.
7. Increasing green infrastructure in the City of Melbourne will help reduce emissions through carbon sequestration and reduced energy demand, while delivering important health benefits through improved air quality, reduced heat stress, as well as enhanced psychological and social wellbeing and resilience.
8. As a major sector and large contributor to GHG, the health sector must be a core focus in City of Melbourne net zero emission strategy will be key to ensuring healthcare facilities are on track to help deliver this goal.

6.2 Further considerations

6.2.1 Research

To date, there is considerable variation in approaches to evaluating the health co-benefits of mitigation strategies (Remais, 2014). The majority of those studies find significant, near term, local health co-benefits that yield net cost savings (Chang, 2017). Most studies highlight the interaction of climate and health policy and the magnitude of potential outcomes rather than specific detailed estimates of health co-benefits for a particular jurisdiction (Chang, 2017).

There is sufficient evidence available in relation to health co-benefits associated with climate mitigation and adaptation action to guide the development and implementation of strategies with a dual health and climate goal in the City of Melbourne in the sectors described.

A detailed assessment of health co-benefits available from a comprehensive range of net zero emissions strategies in the City of Melbourne should be undertaken to inform policy development. Detailed analysis and quantification of the cost and health benefits associated with a range of emissions reductions scenarios would help prioritise the adoption of measures to deliver health gains alongside emissions reductions. Policymakers are encouraged to work with researchers (and vice versa) to develop studies that produce quantifiable, policy-relevant analysis to guide decision-making (Remais, 2014). This will require collaboration across disciplines and agencies to ensure health data and social impact is incorporated into scenario development and subsequent economic modelling. This can be challenging but is necessary if accurate assessments of the health costs of business-as-usual are to inform future policy scenarios. Collaboration with state government will be essential to support data collection, collation and analysis.

6.2.2 Integrating mental health

Specific attention needs to be paid to the mental health risks of unmitigated climate change as well as to the potential for mental health co-benefits associated with emissions reduction policies. While the latter can be substantial, they are also harder to measure, but if understood can provide a powerful rationale as well as motivation and support for action. The inclusion of qualitative surveys in evaluating health impacts in relation to emissions reductions strategies should be utilised to ensure those currently more intangible psychological benefits (like reduced social isolation from walking more, reduced exposure to traffic noise and fumes) are included in assessment of current harms and future co-benefits (de Oliveira, 2016).

However, given the timescales for this type of research can be long, the substantial existing body of literature which provides clear insights into the possible directions for realising co-benefits for the local population should be utilised, and strategies based on those findings developed and implemented.

6.2.3 Health Impact Assessment

The City of Melbourne should utilise Health Impact Assessments (HIA) (with accompanying social and environmental impacts assessment) as a tool for assessing health risks and benefits of all policy decisions. HIA can be used to inform policy decision in relation to health, transport, environment, agriculture, energy, waste, housing and planning (EnHealth, 2017).

6.2.4 Governance to support policy integration

In developing strategies to achieve net zero emissions in the City of Melbourne, it will be necessary to develop governance mechanisms that build the capacity of the city to integrate health in policy development processes related to transport, energy, urban planning, and buildings to ensure health risks and benefits are acknowledged (de Oliveira, 2016). The inclusion of multi-stakeholder networks in policy design can help ensure the measures chosen are effective, acceptable and fit for purpose (de Oliveira, 2016).

6.2.5 Assessing upstream emissions

In addition to reducing emissions that occur in the City of Melbourne, the net zero emissions strategy should also consider opportunities for reducing the region's upstream emissions. Recent studies suggest upstream emissions from urban household consumption are of a similar magnitude to cities' overall territorial emissions and that local policy leverage can have more significant impacts on upstream emissions than is typically assumed (Pichler, 2017).

7. Conclusion

While this review has considered a substantial body of literature (124 studies), it is not exhaustive and does not constitute a complete systematic review. It does however provide an overview of the body of evidence from recent (2008 - current) scientific literature on the about the health and social benefits associated with climate strategies.

In conclusion, the climate and health co-benefits literature is compelling and should be comprehensively utilised by the City of Melbourne to help propel policy development and implementation to realise the often mutually reinforcing and complementary goals of positive health and wellbeing AND arresting global warming.

8. References

AIHW (Australian institute of Health and Welfare), 2016. Australian burden of disease study: impact and causes of illness and death in Australia 2011, AIHW, Canberra.

Alexandri, E. and Jones, P., 2008. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Building and environment*, *43*(4), pp.480-493.

Aleksandrowicz, L., Green, R., Joy, E.J., Smith, P. and Haines, A., 2016. The impacts of dietary change on greenhouse gas emissions, land use, water use, and health: a systematic review. *PloS one*, *11*(11), p.e0165797.

Australian Conservation Foundation, 2018. Think global, act local on climate change. Available at: https://www.acf.org.au/think_global_act_local_on_climate_change Accessed 7 June 2018.

Australian Council of Social Services (ACOSS), The Climate Institute, Brotherhood of St Lawrence, 2017. Empowering disadvantaged households to access affordable, clean energy. Available at: https://www.acoss.org.au/wp-content/uploads/2017/07/ACOSS_BSL_TCI_Empowering-households_27-July-2017.pdf

Australian Bureau of Statistics, 2016. Australian Health Survey: Consumption of Food Groups from the Australian Dietary Guidelines, 2011-12. Available at: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/4364.0.55.012~2011-12~Main%20Features~Lean%20meats%20and%20alternatives~13 Accessed 2 June 2018.

Bain, P.G., Milfont, T.L., Kashima, Y., Bilewicz, M., Doron, G., Garðarsdóttir, R.B., Gouveia, V.V., Guan, Y., Johansson, L.O., Pasquali, C. and Corral-Verdugo, V., 2016. Co-benefits of addressing climate change can motivate action around the world. *Nature Climate Change*, *6*(2), p.154.

Balbus, J.M., Greenblatt, J.B., Chari, R., Millstein, D. and Ebi, K.L., 2014. A wedge-based approach to estimating health co-benefits of climate change mitigation activities in the United States. *Climatic change*, *127*(2), pp.199-210.

Banwell, N.; Rutherford, S.; Mackey, B.; Street, R.; Chu, C. 2018. Commonalities between Disaster and Climate Change Risks for Health: A Theoretical Framework. *Int. J. Environ. Res. Public Health*, *15*, 538.

Black, MT, Karoly, DJ & King, AD., 2015. *'The contribution of anthropogenic forcing to the Adelaide and Melbourne heatwaves of January 2014.'* In Explaining Extreme Events of 2014 from a Climate Perspective. Bulletin of the American Meteorological Society. 96 (12), S144–S148.

Bowen, K J and Parry, M. 2015. *Green infrastructure and its tri-benefits: health, environment and economic*. City of Melbourne.

Bowen, K.J. and Lynch, Y., 2017. The public health benefits of green infrastructure: the potential of economic framing for enhanced decision-making. *Current Opinion in Environmental Sustainability*.

Buonocore, J.J., Luckow, P., Norris, G., Spengler, J.D., Biewald, B., Fisher, J. and Levy, J.I., 2016. Health and climate benefits of different energy-efficiency and renewable energy choices. *Nature Climate Change*, *6*(1), p.100.

California Department of Public Health, Climate Change and Health Impacts. Available at: https://www.cdph.ca.gov/Programs/OHE/Pages/CCHEP.aspx Accessed 13 June 2018.

Carthey J, Chandra V, Loosemore M., 2009. Adapting Australian health facilities to cope with climate-related extreme weather events. J Facil Manage.7(1), pp.36–51.

Chapman, R., Howden-Chapman, P., Viggers, H., O'Dea, D. and Kennedy, M., 2009. Retrofitting houses with insulation: a cost–benefit analysis of a randomised community trial. *Journal of Epidemiology & Community Health*, *63*(4), pp.271-277.

Cheng, J.J. and Berry, P., 2013. Health co-benefits and risks of public health adaptation strategies to climate change: a review of current literature. *International journal of public health*, *58*(2), pp.305-311.

Climate and Health Alliance, Global Green and Healthy Hospitals Pacific Region. Available at: http://www.caha.org.au/globalgreen_healthyhospitals Accessed 18 May 2018.

Climate Change Authority, Opportunities to reduce light vehicle emissions in Australia. Available at:

http://www.climatechangeauthority.gov.au/reviews/light-vehicle-emissions-standards-australia/opportunities-reduce-light-vehicle-emissions Accessed 4 June 2018.

Creutzig, F., Mühlhoff, R. and Römer, J., 2012. Decarbonizing urban transport in European cities: four cases show possibly high co-benefits. *Environmental Research Letters*, *7*(4), p.044042.

Cunningham, M. 2017. Air quality warning for Victorian asthma sufferers, *The Age*, 13 May. Available at: https://www.theage.com.au/national/victoria/air-quality-warning-for-victorian-asthma-sufferers-20170512-gw3whe.html

Curtis, S.; Fair, A.; Wistow, J.; Val, D.V.; Oven, K., 2017. Impact of extreme weather events and climate change for health and social care systems. *Environ. Health*, *16*, 128.

Daley M, Rissel C, Lloyd B. All dressed up and nowhere to go? 2007. A qualitative research study of the barriers and enablers to cycling in inner Sydney. *Road and Transport Research*; 16(4): 42–52.

D'Amato, G., Baena-Cagnani, C.E., Cecchi, L., Annesi-Maesano, I., Nunes, C., Ansotegui, I., D'Amato, M., Liccardi, G., Sofia, M. and Canonica, W.G., 2013. Climate change, air pollution and extreme events leading to increasing prevalence of allergic respiratory diseases. *Multidisciplinary respiratory medicine*, *8*(1), p.12.

Dean, A. and Green, D., 2018. Climate change, air pollution and human health in Sydney, Australia: A review of the literature. *Environmental Research Letters*, *13*(5), p.053003.

Deloitte Access Economics, 2016. The economic cost of the social impact of natural disasters, Report for Australian Business Roundtable for Disaster Resilience & Safer Communities. Available at: http://australianbusinessroundtable.com.au/our-research/social-costs-report

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A.G., Mittal, N., Feliu, E. and Faehnle, M., 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, *146*, pp.107-115.

de Oliveira, J.A.P. and Doll, C.N., 2016. Governance and networks for health co-benefits of climate change mitigation: lessons from two Indian cities. *Environment international*, *97*, pp.146-154.

Department of Environment and Conservation (NSW), 2004. Investing in our catchments: Water quality and river health.

Doick, K.J., Peace, A. and Hutchings, T.R., 2014. The role of one large greenspace in mitigating London's nocturnal urban heat island. *Science of the total environment*, *493*, pp.662-671.

Eckelman, M.J. and Sherman, J., 2016. Environmental impacts of the US health care system and effects on public health. *PLoS One*, *11*(6), p.e0157014.

enHealth 2017, Health Impact Assessment Guidelines, accessed 15 May 2018,

<http://www.health.gov.au/internet/main/publishing.nsf/content/A12B57E41EC9F326CA257BF0001F9E7D/$File/Health-Impact-Assessment-Guidelines.pdf>

Environmental Justice Australia, 2014. Clearing the air: Why Australia urgently needs effective national air pollution laws. Available at: http://envirojustice.org.au/sites/default/files/files/Submissions%20and%20reports/Envirojustice_air_pollution_report_final.pdf

Environmental Justice Australia, 2017. Toxic and terminal: How the regulation of coal-fired power stations fails Australian communities. Available at: http://www.envirojustice.org.au/powerstations/

Food and Agriculture Organisation, 2010. Sustainable diets and biodiversity: directions and solutions for policy, research and action. Proceedings of the International Scientific Symposium: Biodiversity and Sustainable Diets United Against Hunger, Rome.

Friel, S., 2010. Climate change, food insecurity and chronic diseases: sustainable and healthy policy opportunities for Australia. *New South Wales Public Health Bulletin*, *21*(6), pp.129-133.

Friel, S., Barosh, L.J. and Lawrence, M., 2014. Towards healthy and sustainable food consumption: an Australian case study. *Public health nutrition*, *17*(5), pp.1156-1166.

Global Green and Healthy Hospitals, Who we are, Available at: https://www.greenhospitals.net/who-we-are/ Accessed 3 June 2018.

Global Green and Healthy Hospitals, Action, Available at https://www.greenhospitals.net/action/ Accessed 5 June 2018.

Grabow, M.L., Spak, S.N., Holloway, T., Stone Jr, B., Mednick, A.C. and Patz, J.A., 2012. Air quality and exercise-related health benefits from reduced car travel in the midwestern United States. *Environmental health perspectives*, *120*(1), p.68.

Gundersen Health System, 2016 https://www.hospitalesporlasaludambiental.net/wp-content/uploads/2016/10/Leadership-and-Energy-Capturing-the-Wind's-Energy-to-Create-Clean-Electricity-PGH-Gundersen-USA.pdf

Haines, A., McMichael, A.J., Smith, K.R., Roberts, I., Woodcock, J., Markandya, A., Armstrong, B.G., Campbell-Lendrum, D., Dangour, A.D., Davies, M. and Bruce, N., 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *The Lancet*, *374*(9707), pp.2104-2114.

Hanjra, M.A. and Qureshi, M.E., 2010. Global water crisis and future food security in an era of climate change. Food Policy, 35(5), pp.365-377.

Hall, GV, Hanigan, IC, Dear KB, & Vally, H,. 2011. *'The influence of weather on community gastroenteritis in Australia'* Epidemiol. Infect., 139, pp.927–936. doi:10.1017/ S0950268810001901.

Hanigan, IC, Butler, CD, Kokic, PN, & Hutchinson, MF,. 2012, *'Suicide and drought in New South Wales, Australia, 1970– 2007*,*'* Proceedings of the Royal Academy of Sciences, 35, 13950–13955.

Hanna, E.G., Kjellstrom, T., Bennett, C. and Dear, K., 2011. Climate change and rising heat: population health implications for working people in Australia. *Asia Pacific Journal of Public Health*, *23*(2_suppl), pp.14S-26S.

Hansen, A. et al, The Effect of Heat Waves on Mental Health in a Temperate Australian City Environ Health Perspect. 2008 Oct; 116(10): 1369–1375. Published online 2008 Jun 30. doi: 10.1289/ehp.11339

Health Promotion Service, 2009. Cycling around the University of Sydney and Royal Prince Alfred Hospital. Camperdown: Sydney South West Area Health Service. Available from: http://www.cs.nsw.gov.au/pophealth/healthpro/physical/pdf/ RPAH_SydUni_cyclemap.pdf

Hsiang, S.M., Burke, M. and Miguel, E., 2013. Quantifying the influence of climate on human conflict. *Science*, *341*(6151), p.1235367.

Hughes, L, Hanna, E, & Fenwick, J., 2016. *'The Silent Killer: Climate change and the health impacts of extreme heat'* Climate Council of Australia. 2016: Climate Council of Australia.

International Agency for Research on Cancer (IARC - WHO), 2013. "IARC: Outdoor air pollution a leading environmental cause of cancer deaths", *Media release*, 17 October 2013, available at http://www.iarc.fr/en/media-centre/iarcnews/pdf/ pr221_E.pdf

IPCC, Climate Change, 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge.

Jarrett, J., Woodcock, J., Griffiths, U.K., Chalabi, Z., Edwards, P., Roberts, I. and Haines, A., 2012. Effect of increasing active travel in urban England and Wales on costs to the National Health Service. *The Lancet*, *379*(9832), pp.2198-2205.

Johansson, C., Burman, L. and Forsberg, B., 2009. The effects of congestions tax on air quality and health. *Atmospheric Environment*, *43*(31), pp.4843-4854.

Kjellstrom, T. and Weaver, H.J., 2009. Climate change and health: impacts, vulnerability, adaptation and mitigation. *New South Wales Public Health Bulletin*, *20*(2), pp.5-9.

Kjellstrom, T. and McMichael, A.J., 2013. Climate change threats to population health and well-being: the imperative of protective solutions that will last. *Global health action*, *6*(1), p.20816.

Kjellstrom, T, Briggs, D, Freyberg, C, Lemke, B, Otto, M, & Hyatt, O., 2016. *'Heat, human performance, and occupational health: A key issue for the assessment of global climate change impacts'* Annual Review of Public Health, 37, 97–112.

Klein, A., 2017. Workers warm up big cities on weekdays. *New Scientist*. *233(3110)* 28 January, p.11.

Koowerup Regional Health Service, 2017. 2020 Challenge Climate Champion Case Study - Resiliency - Kooweerup Regional Health Service (KRHS). Available at: https://www.greenhospitals.net/wp-content/uploads/2017/09/2020-Challenge-Climate-Champion-Case-Study-Resiliency-Australia.pdf

Kwan S.C., Hashim J.H., 2016. A review on co-benefits of mass public transportation in climate change mitigation. Sustainable Cities and Society, 22, pp. 11-18.

Landauer, M., Juhola, S. and Söderholm, M., 2015. Inter-relationships between adaptation and mitigation: a systematic literature review. *Climatic change*, *131*(4), pp.505-517.

Larouche, R., 2012. The environmental and population health benefits of active transport: A review. In *Greenhouse Gases-Emission, Measurement and Management*. InTech.

Levy, J.I., Nishioka, Y. and Spengler, J.D., 2003. The public health benefits of insulation retrofits in existing housing in the United States. *Environmental Health*, *2*(1), p.4.

Lewis, SC, & Karoly, DJ,. 2014, *'The role of anthropogenic forcing in the record 2013 Australia-wide annual and spring temperatures'.* In Explaining Extremes of 2013 from a climate perspective. Bulletin of the American Meteorological Society. 95 (9), S31–S34

Lindsay, G., Macmillan, A. and Woodward, A., 2011. Moving urban trips from cars to bicycles: impact on health and emissions. *Australian and New Zealand journal of public health*, *35*(1), p.54.

Mayrhofer, J., 2016. The science and politics of co-benefits in climate policy, Environmental Science & Policy 57, pp. 22–30.

Macdiarmid, J.I., Kyle, J., Horgan, G.W., Loe, J., Fyfe, C., Johnstone, A. and McNeill, G., 2012. Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet?. *The American journal of clinical nutrition*, *96*(3), pp.632-639.

Maibach, E.W., Nisbet, M., Baldwin, P., Akerlof, K. and Diao, G., 2010. Reframing climate change as a public health issue: an exploratory study of public reactions. *BMC public health*, *10*(1), p.299.

Malik, A., Lenzen, M., McAlister, S. and McGain, F., 2018. The carbon footprint of Australian health care. *The Lancet Planetary Health*, *2*(1), pp.e27-e35.

Mallon, K., Hamilton, E., Black, M. and Beem, B., 2013. Adapting the community sector for climate extremes. *National Climate Change Adaption Research Facility, Gold Coast*.

McKinley, G., Zuk, M., Höjer, M., Avalos, M., González, I., Iniestra, R., Laguna, I., Martínez, M.A., Osnaya, P., Reynales, L.M. and Valdés, R., 2005. Quantification of local and global benefits from air pollution control in Mexico City. *Environ Sci Technol. 39*(7) pp.1954-61.

MacNeill, A.J., Lillywhite, R. and Brown, C.J., 2017. The impact of surgery on global climate: a carbon footprinting study of operating theatres in three health systems. *The Lancet Planetary Health*, *1*(9), pp.e381-e388.

McMichael, A.J. and Lindgren, E., 2011. Climate change: present and future risks to health, and necessary responses. *Journal of internal medicine*, *270*(5), pp.401-413.

Milner, J., Davies, M. and Wilkinson, P., 2012. Urban energy, carbon management (low carbon cities) and co-benefits for human health. *Current Opinion in Environmental Sustainability*, *4*(4), pp.398-404.

Myers, T.A., Nisbet, M.C., Maibach, E.W. and Leiserowitz, A.A., 2012. A public health frame arouses hopeful emotions about climate change. *Climatic change*, *113*(3-4), pp.1105-1112.

Naylor, C. and Appleby, J., 2012. *Sustainable health and social care: connecting environmental and financial performance*. King's Fund.

Nemet, G.F., Holloway, T. and Meier, P., 2010. Implications of incorporating air-quality co-benefits into climate change policymaking. *Environmental Research Letters*, *5*(1), p.014007.

NHS Sustainable Development Unit., 2008, updated 2009, 2016. NHS England carbon emissions carbon footprinting report. Available at: http://www.sdu.nhs.uk/documents/publications/1263313924_jgyW_nhs_england_carbon_emissions_carbon_footprinting_r.pdf

Nisbet, M.C., 2009. Communicating climate change: Why frames matter for public engagement. *Environment: Science and policy for sustainable development*, *51*(2), pp.12-23.

Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M. and Williams, N.S., 2015. Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning*, *134*, pp.127-138.

Organisation for Economic Cooperation and Development (OECD), 2014. The Cost of Air Pollution: Health Impacts of Road Transport. Available at: http://www.oecd.org/env/the-cost-of-air-pollution-9789264210448-en.htm

Okvat, H.A. and Zautra, A.J., 2011. Community gardening: A parsimonious path to individual, community, and environmental resilience. *American journal of community psychology*, *47*(3-4), pp.374-387.

Paranjothy, S., Gallacher, J., Amlôt, R., Rubin, G.J., Page, L., Baxter, T., Wight, J., Kirrage, D., McNaught, R. and Palmer, S.R., 2011. Psychosocial impact of the summer 2007 floods in England. *BMC public health*, *11*(1), p.145.

Pencheon, D., 2009. Health services and climate change: what can be done? *Journal of Health Services Research and Policy*, Vol 14(1), pp.2-4).

Petrovic, N., Madrigano, J. and Zaval, L., 2014. Motivating mitigation: when health matters more than climate change. *Climatic Change*, *126*(1-2), pp.245-254.

Public Health Association of Australia, 2014. Safe Climate Policy, Available at: https://www.phaa.net.au/documents/item/255 Accessed 28 May 2018.

Quam, V., G M, Rocklöv, J, Quam, MBM, & Lucas, RAI., 2017. Assessing Greenhouse Gas Emissions and Health Co-Benefits: A Structured Review of Lifestyle-Related Climate Change Mitigation Strategies. *International Journal of Environmental Research and Public Health., 14*(5), International journal of environmental research and public health. 2017, Vol.14(5).

Remais, J. et al. 2017, Estimating the Health Effects of Greenhouse Gas Mitigation Strategies: Addressing Parametric, Model, and Valuation Challenges, Environ Health Perspect. 2014 May; 122(5): 447–455.

Roy, R. and Braathen, N. 2017. The Rising Cost of Ambient Air Pollution thus far in the 21st Century: Results from the BRIICS and the OECD Countries, *OECD Environment Working Papers*, No. 124, OECD Publishing, Paris. Available at http://dx.doi.org/10.1787/d1b2b844-en Accessed 5 June 2018.

Royal Melbourne Hospital, 2017. Case Study: Reducing Waste from Operating Theatres. Available at: https://www.hospitalesporlasaludambiental.net/wp-content/uploads/2018/02/Reducing-Waste-from-Operating-Theatres-Australia.pdf

Santamouris, M., 2014. Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar energy*, *103*, pp.682-703.

Scarborough, P., Allender, S., Clarke, D., Wickramasinghe, K. and Rayner, M., 2012. Modelling the health impact of environmentally sustainable dietary scenarios in the UK. *European journal of clinical nutrition*, *66*(6), p.710.

Schwerdtle, P., Bowen, K. and McMichael, C., 2018. The health impacts of climate-related migration. *BMC medicine*, *16*(1), p.1.

Sherman, J. and McGain, F., 2016. Environmental sustainability in anesthesia: pollution prevention and patient safety. *Advances in Anesthesia*, *34*(1), pp.47-61.

Singh, S., Hanna, E.G. and Kjellstrom, T., 2013. Working in Australia's heat: Health promotion concerns for health and productivity. *Health promotion international*, *30*(2), pp.239-250.

Smith, K. et al Energy and Human Health Annu. Rev. Public Health 2013. 34:159–88

Smith, K.R., A. Woodward, D. Campbell-Lendrum, D.D. Chadee, Y. Honda, Q. Liu, J.M. Olwoch, B. Revich, and R. Sauerborn, 2014: Human health: impacts, adaptation, and co-benefits. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 709-754.

South, E.C., Hohl, B.C., Kondo, M.C., MacDonald, J.M. and Branas, C.C., 2018. Effect of Greening Vacant Land on Mental Health of Community-Dwelling Adults: A Cluster Randomized Trial. *JAMA Network Open*, *1*(3), pp.e180298-e180298.

Southern Cross Care, 2016 https://www.greenhospitals.net/wp-content/uploads/2017/12/Souther-Cross-Care-Australia.pdf

State Government of Victoria, 2009, *January 2009 heatwave in Victoria: An assessment of health impacts*. Department of Health and Human Services Victoria, Melbourne.

State Government of Victoria, 2014, *The health impacts of the January 2014 heatwave in Victoria*. Department of Health Victoria, Melbourne.

State of Victoria, 2017a, *The November 2016 Victorian epidemic thunderstorm asthma event: an assessment*
of the health impacts: The Chief Health Officer's Report, 27 April 2017. Department of Health and Human Services Victoria, Melbourne.

State of Victoria, 2017b, *Review of the response to the thunderstorm asthma event of 21–22 November 2016: Final report*. Inspector-General for Emergency Management, Melbourne.

Steffen, W, Hughes, L, Alexander, D & Rice, M., 2017a, *'Cranking Up The Intensity: Climate Change and Extreme Weather Events',* Climate Council of Australia, Available at: https://www.climatecouncil.org.au/uploads/1b331044fb03fd0997c4a4946705606b.pdf

Tallis, M., Taylor, G., Sinnett, D. and Freer-Smith, P., 2011. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. *Landscape and Urban Planning*, *103*(2), pp.129-138.

Telfer B, Rissel C, Bindon J, Bosch T., 2006. Encouraging cycling through a pilot cycling proficiency training program among adults in central Sydney. *J Sci Med Sport*; 9(1–2): 151–6. doi:10.1016/j.jsams.2005.06.001.

Thompson, T.M., Rausch, S., Saari, R.K. and Selin, N.E., 2014. A systems approach to evaluating the air quality co-benefits of US carbon policies. *Nature Climate Change*, *4*(10), p.917.

Tofa, M., Beggs, P.J., & Gissing, A. 2017, *Thunderstorm Asthma: Current knowledge, approaches to monitoring and forecasting, and options for mitigation and preparedness*, Report prepared for the Inspector-General for Emergency Management (IGEM); Victoria. Risk Frontiers, Sydney.

Townsend, M. and Weerasuriya, R., 2010. Beyond blue to green: The benefits of contact with nature for mental health and well-being. *Melbourne, Australia: Beyond Blue Limited*.

United States Environmental Protection Authority, 2017, Health, Energy Efficiency and Climate Change. Available at: https://www.epa.gov/indoor-air-quality-iaq/health-energy-efficiency-and-climate-change Accessed 3 June 2018.

Uniting Care Community, 2016, Case Study: Community Energy Efficiency Program, Uniting Care Community and Blue Care, Australia. Available at: https://www.greenhospitals.net/wp-content/uploads/2017/12/Community-Energy-Efficiency-Program-Uniting-Care-Queensland-Australia.pdf

Ürge-Vorsatz, D. and Herrero, S.T., 2012. Building synergies between climate change mitigation and energy poverty alleviation. *Energy policy*, *49*, pp.83-90.

van der Linden, S., Maibach, E. and Leiserowitz, A., 2015. Improving public engagement with climate change: Five “best practice” insights from psychological science. *Perspectives on Psychological Science*, *10*(6), pp.758-763.

Varghese, B.M., Hansen, A., Bi, P. and Pisaniello, D., 2018. Are workers at risk of occupational injuries due to heat exposure? A comprehensive literature review. *Safety Science*.

Victorian Auditor General’s Office (VAGO), 2018. Improving Victoria’s Air Quality, Independent assurance report to Parliament**,** March. Available at: https://www.audit.vic.gov.au/sites/default/files/2018-03/20180308-Improving-Air-Quality.pdf

Voice, M 2015. Who’s been affected by Australia’s extreme heat? Everyone. The Conversation, 30 January. Available at: https://theconversation.com/whos-been-affected-by-australias-extreme-heat-everyone-36116 Accessed 25 June 2018.

Wales, N., Khanjanasthiti, I., Savage, S. and Earl, G., 2012. Climate change resilience of Melbourne. The Climate Institute, Sydney.

Watts, N. et al. 2015. Health and climate change: policy responses to protect public health, The Lancet Commission on Health and Climate, Vol 386 November 7.

Watts, N, et al., 2017. *‘The Lancet Countdown: tracking progress on health and climate change*,*’* Lancet, 389, 10074, pp. 1151–1164

Workman, A., Blashki, G., Bowen, K.J., Karoly, D.J. and Wiseman, J., 2018. The Political Economy of Health Co-Benefits: Embedding Health in the Climate Change Agenda. *International journal of environmental research and public health*, *15*(4), p.674.

World Health Organization (WHO), 2011. Health in the Green Economy, Co-benefits to health of climate change mitigation—housing sector. World Health Organization.

World Health Organization, 2018. WHO Ambient air pollution database. Available at: http://www.who.int/airpollution/en/ Accessed 8 June 2018.

Wolkinger, B., Haas, W., Bachner, G., Weisz, U., Steininger, K., Hutter, H.P., Delcour, J., Griebler, R., Mittelbach, B., Maier, P. and Reifeltshammer, R., 2018. Evaluating Health Co-Benefits of Climate Change Mitigation in Urban Mobility. *International journal of environmental research and public health*, *15*(5).

Zhang, B., Gao, J.X. and Yang, Y., 2014. The cooling effect of urban green spaces as a contribution to energy-saving and emission-reduction: A case study in Beijing, China. *Building and Environment*, *76*, pp.37-43.

Appendix A

The following table provides examples of existing initiatives that deliver climate and health co-benefits:

INITIATIVE	CLIMATE AND HEALTH CO-BENEFITS
Spain	
The Bicing public bicycling sharing initiative in Barcelona promotes bicycling as a common means of transport	As a results of substituting car journeys by Bicing, annual CO2 emissions in Barcelona were reduced by an estimated 9062 MT, physical activity was increased, and 12.28 deaths avoided annually (Gao, 2018).
Sweden	
An initiative in Stockholm, Sweden, introduced a road pricing system to improve air quality and reduce traffic congestion	The introduction of road use charges led to a 15% reduction in total road use within the area where charges applied. Total traffic emissions of NO_x and PM10 in this area fell by 8.5% and 13%, respectively. This initiative is estimated to avoid 28 premature deaths each year (Johansson, 2009).
Philadelphia	
An initiative to clean up and 'green' unused public spaces in Philadelphia	Planting trees and grass and removal of waste led to substantial improvement in mental health: residents were happier and reported a 40% decline in depression (in poorer areas, residents reported a 70% drop in depression) (South, 2018).
New Zealand	
A pilot project to retrofit insulation into households in low income communities where at least one person suffered from respiratory illness. Measured personal comfort, healthcare utilisation, energy use, and GHG emissions.	This intervention reduced hospital admissions, delivered energy savings and CO_2 savings, and delivered net benefits of $1574 per household (Chapman, 2008).

INITIATIVE	CLIMATE AND HEALTH CO-BENEFITS
Global	
The Global Green and Healthy Hospitals (GGHH) network of hospitals, health facilities, and health organisations established in 2012 now has over 1000 members in 54 countries, representing over 32,000 hospitals and health centres. The Pacific region of this network (Australia and New Zealand) has around 40 members, representing 800 hospitals and health services, including Melbourne Health (CAHA, 2018). This is set to grow rapidly in Victoria, with the Department of Health and Human Service joining GGHH in 2018, providing the opportunity for all of the state's public health services to participate in and access the network.	Hospitals and health services participating in the GGHH Health Care Climate Challenge have pledged to reduce emissions by 16 million metric tonnes by 2020. This is equivalent to: • one year of carbon emissions from 4 coal-fired power plants • energy use of 1.7 million (US) homes for one year • savings of $1.7 billion in healthcare costs related to air pollution • emissions reductions equivalent to running 4,000 wind turbines for one year These initiatives will reduce morbidity and mortality in local communities and the economic savings will provide additional health services.