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Climate and Health Alliance

HEALTHY TRANSPORT
CLEANER AIR + CONNECTED COMMUNITIES

October 2023 | Report

Clearing the air

Transport decarbonisation and our health

Contents

About the Climate and Health Alliance

The Climate and Health Alliance (CAHA) is a national health promotion charity and the peak body on climate change and health in Australia. CAHA is an alliance of organisations within the health sector working together to raise awareness about the health risks of climate change and the health benefits of emissions reductions. The membership of CAHA includes a broad cross-section of health sector stakeholders with over 100 member organisations (Appendix 1), representing healthcare professionals from a range of disciplines, as well as healthcare service providers, institutions, academics, researchers, and consumers.

Acknowledgement

The Climate and Health Alliance recognises Aboriginal and Torres Strait Islander People as the traditional custodians of the land on which we live and work, and acknowledge that sovereignty of the land we call Australia has never been ceded. We commit to listening to and learning from Aboriginal and Torres Strait Islander people about how we can better reflect Indigenous ways of being and knowing in our work.

Clearing the air

Transport decarbonisation and health

This report is based on a review commissioned by CAHA from Professor Mark Stevenson, Avita Streatfield and Ferdinand Balfoort at the University of Melbourne in 2023. The report also includes additional material prepared by Clare Walter, Chelsea Hunnisett, Remy Shergill and Roland Sapsford at the Climate and Health Alliance, and has been edited for publication.

Abbreviations

ACC	Accident Compensation Commission
CO2	Carbon dioxide
EMM	Electric micromobility
ICE	Internal combustion engine
MaaS	Mobility-as-a-Service
PM2.5, PM10	Particulate matter
SDGs	Sustainable Development Goals
EV	Electric Vehicle

A note from the Chair

The evidence on climate change is clear – without rapid, ambitious and decisive action the world as we know it will be altered irrevocably and human health will suffer. In Australia, frequent bushfires, droughts, heatwaves and floods serve as all too frequent reminders that even with ambitious action, our climate has already changed and we must adapt at the same time as reducing emissions.

In 2021, the Climate and Health Alliance (CAHA) released its 'Healthy, Regenerative and Just' Framework. The Framework presents an inclusive vision for coordinated action that supports Australia to deliver on its obligations under the Paris Agreement, and to do so in a way that promotes health and wellbeing, a regenerative economy, and social, environmental and cultural justice in the context of a changing climate. This framework is widely supported by the health sector.

The transport sector is responsible for almost 20% of Australia's emissions. This represents both an enormous challenge, and enormous opportunity to achieve better climate and health outcomes in this country

Healthy, Regenerative and Just includes a call for accelerated transition to healthy, equitable and low-emission transport. This means moving away from heavy reliance on fossil fuel based car and truck transport towards a healthier mix of transport options as well as the electrification of the nation's road transport fleet. Together these actions will reduce emissions while improving overall health and wellbeing.

This rapid evidence review seeks to delve deeper into the challenges and opportunities for health and climate through decarbonisation of the transport sector. It analyses the interaction between transport, health and climate and sets out a series of evidence based recommendations for how Australia can move forward for the wellbeing of current and future generations. The evidence here provides a clear foundation for the health, transport and environment sectors to take action.

At CAHA we recognise climate change as the biggest health threat of the 21st century. It is incumbent on our policy makers and political leaders to act on the evidence as quickly as possible. We present this paper as an opportunity for progress.

Frances Peart

President and Board Chair
Climate and Health Alliance

Introduction

Australia's over-reliance on a transport system powered by fossil fuels and combustion engines has resulted in detrimental environmental and population health impacts. Road transport emissions have grown more than from any other sector in Australia, increasing nearly 60% since 1990. Australia's per capita road transport emissions are 45% higher than the OECD average (Climate Council Australia 2017). The significant health consequences arising from road transport emissions are an increasing concern.

The good news is that many opportunities exist to decarbonise Australia's road transport system. We already know that transitioning from a 20th-century fossil-fuelled transport system to a zero-emission system will deliver environmental and health benefits. A key part of this is a shift from heavy dependence on private motor vehicles for most trips, to greater use of active transport modes, such as walking and cycling for local travel. Decarbonisation also requires increased investment in public transport infrastructure and services. This reduces emissions, increases physical activity, and improves air quality levels (Kwan et al. 2017). As well as active modes, electric micromobility (EMM), including e-scooters, e-bikes, and e-mopeds, can be used for the start and end of journeys (Anderson et al. 2022). EMM is better for the environment than fossil-fuelled transport, even considering emissions over their life cycle. They also provide physical and mental health benefits.

We must also adopt low- and zero-emission private and public vehicles. Driving fully electric vehicles can also reduce greenhouse emissions and air pollution. Supporting the uptake of electric vehicles for enhanced public transport will produce health co-benefits while decarbonising our transport system.

Actions to decarbonise need careful planning and efforts to improve transport equity. Enabling people to shift from passive to active transport requires an increase in safe infrastructure for people who are walking and cycling. More EMM requires aligned policies and infrastructure to ensure their safe use. Over reliance on private electric vehicles alone can cause unintended negative consequences, such as increased energy needed for recharging batteries, and health inequity for people facing barriers to new transport options. These trade-offs must be well understood as part of a healthy and just approach to transport decarbonisation.

This report is a high-level evidence review, providing insights on how best to decarbonise the transport system to achieve health co-benefits.

Climate impacts of Australia's transport system

The Commonwealth Government has committed to a 43% reduction in greenhouse gas emissions by 2030 via the Climate Change Bill 2022. However, Australia's emissions must be reduced by 74% by 2030 in order to limit global warming to the Paris Agreement goal of 1.5 °C (ClimateWorks Australia 2020). In Australia, road transport emissions have grown more than any other sector, increasing nearly 60% since 1990 (Australian Government 2017) and accounting for 19% of Australia's overall emissions (DCCEEW 2023). This has resulted in Australia's per capita road transport emissions being 45% higher than the OECD average (Climate Council Australia 2017).

Australia's over-reliance on a transport system powered by fossil fuels and combustion engines has resulted in detrimental environmental and population health impacts. These impacts arise from the use of private motor vehicles reliant on petrol and diesel fuels. These fuels produce greenhouse gases, with CO_2 representing 99% of transport-related emissions. The remaining 1% is methane, nitrous oxide, and particulate matter (Brand et al. 2021). The challenge of addressing these transport emissions remains critical for safeguarding human and environmental health in a warming climate.

Australia's urban landscape and its impacts on high-emissions private vehicle use

Globally, transport emissions comprise about one-quarter of total greenhouse gas emissions (IEA 2022). In many highly motorised countries, transport emissions are much higher (Yadav et al. 2023). In Australia, the transport sector is the third largest source of greenhouse gas emissions, with cars being responsible for about half of all transport emissions (Australian Government 2017). Highly motorised countries like Australia have very high private car ownership, and minimal public and active transport participation (Figure 1).

A key reason for car dependence in Australia is that most of the population lives in sprawling cities with limited public transport. This is particularly acute throughout the peri-urban areas of Australian cities, where people rely on private cars for transport (Kent et al. 2019). Regions reliant on private car use often lack amenable and safe infrastructure to accommodate other road users; this is partly due to an auto-centric past combined with land-use policies favouring housing affordability on the urban fringe (Bosman and Dodson 2014; Scheurer and Curtis 2019).

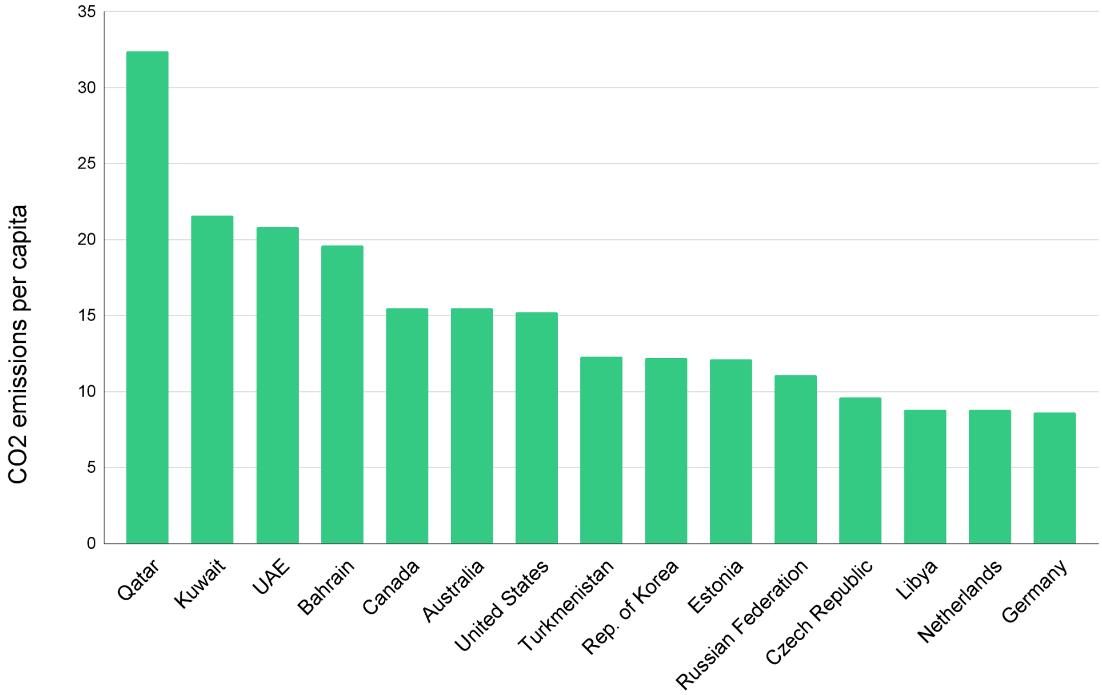

Figure 1. Highest CO_2 polluters per capita by country. Figure 1. provides a comparison of per capita carbon emissions across various countries. Source: The World Bank EN.ATM.CO2E.PC (2018)

As a result of Australia's sprawling cities, more than 80% of daily household trips for work or education are by private motor vehicles; more than 50% of those are for commuting and trips average just 17 km (ABS 2021). Australian households also have high car ownership, with an average of 1.8 private vehicles per household and more than half of Australian households owning two vehicles (ABS 2021).

Sprawling residential-only development patterns that lack ready access to key services such as schooling, shops, and healthcare dominate many Australian suburbs. Lower-density suburban areas also tend to lack the social infrastructure of denser urban areas. These conditions provide fewer opportunities for social interaction and activities (Dutta et al. 2023). Such suburban areas limit the ability of children and adults to walk or cycle (ABS 2016). Low-density housing in such areas renders public transport cost-prohibitive, producing a reliance on private motor vehicles. This increases exposure to risks associated with traffic speed and volume, vehicle emissions, and physical inactivity (Stevenson et al. 2016).

Health impacts of Australia's transport system

As is, our transport system creates an array of negative health impacts, driven by:

- Air pollution produced by vehicles, either from burning fuel or from mechanical abrasion
- High car dependency leading to physical inactivity, road trauma and noise pollution

Negative health impacts from our transport system include injury and chronic diseases, including cardiac arrests, asthma, respiratory disease, strokes, diabetes, lung cancer, adverse birth outcomes, impaired cognitive development in children and accelerated cognitive decline in elderly people.

Air pollution

The cars and trucks on Australian roads are a major source of air pollution. Vehicles produce air pollution in two ways:

- Tailpipe emissions: When ICE vehicles burn petrol or diesel fuel, they release tailpipe emissions comprising a range of harmful air pollutants, including nitrogen dioxide, sulphur dioxide, volatile organic compounds, and fine particulate matter ($PM_{2.5}$).
- Non-tailpipe emissions: All vehicles produce air pollutants via mechanical abrasion – like the wearing of brakes and tyres, and road dust resuspension. Non-tailpipe emissions largely comprise larger particulate matter (PM_{10}).

Traffic-related air pollution has far-reaching health impacts, placing a significant burden on the healthcare system and affecting productivity (Figure 2). A recent estimate from the University of Melbourne suggests traffic-related air pollution is linked each year to 11,000 premature deaths, 19,000 hospitalisations due to cardiovascular and respiratory disease, and 66,000 asthma cases in Australia (Walter et al. 2023). There is growing evidence of the impact of air pollution on human cognition. Increased exposure to ambient air pollution is linked to impaired neurodevelopment in children (Morgan et al. 2023; Zou et al. 2023). Exposure to traffic-related air pollution may increase the risk of dementia among people with mild cognitive impairment (Urbano et al. 2023).

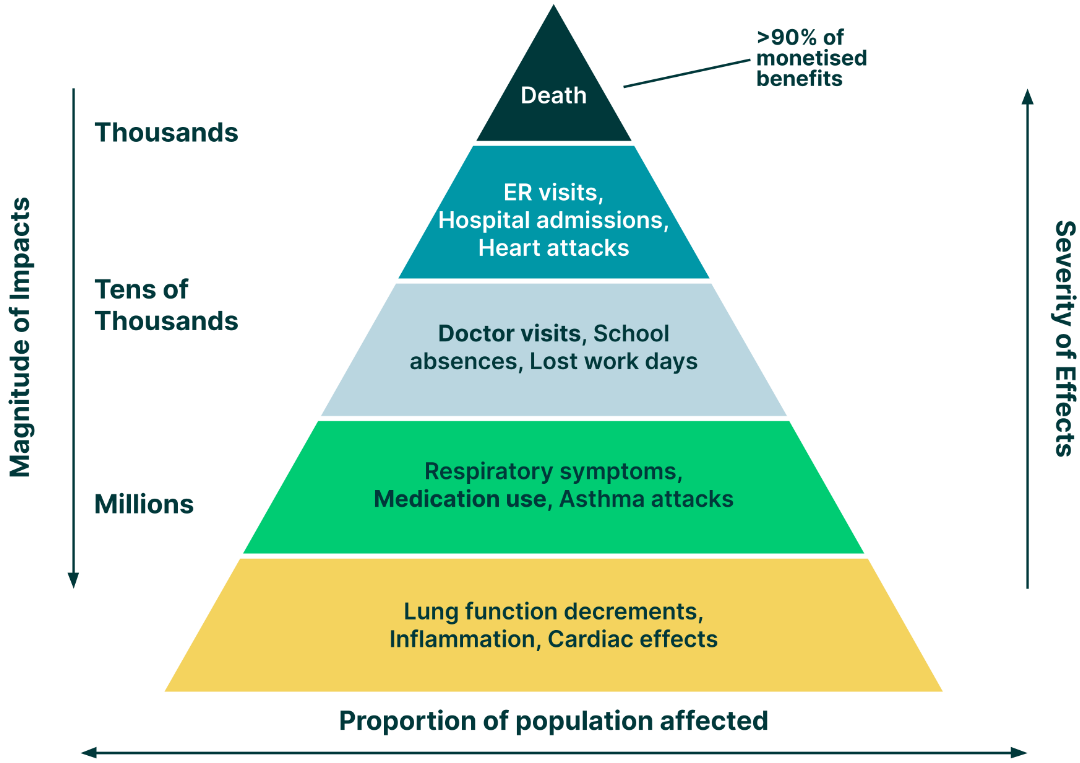

Figure 2. Pyramid of effects from air pollution. Source: US EPA, BenMAP

Air pollution disproportionately affects certain populations in Australia:

- Babies and children, including before birth
- Older age groups
- Those with pre-existing health conditions
- Aboriginal and Torres Strait Islander Peoples
- Lower socioeconomic groups

Babies and children are particularly affected by traffic-related air pollution. Age-stratified Australian studies have revealed respiratory risk estimates in the 0-4 yr age group that are two to threefold higher compared to adults (Walter et al., 2021). Air pollution-related deaths peak among neonatal babies (in the first 27 days of life), often due to lower respiratory infections caused by particulate matter (Health Effects Institute 2021). Deaths then peak again in the older age groups, as air pollution contributes to lower-respiratory infections as well as non-communicable diseases that develop over time, like ischaemic heart disease, stroke, chronic obstructive pulmonary disease, and lung cancer (Health Effects Institute 2021).

Particulate matter
Fine particulate matter ($PM_{2.5}$) is an air pollutant released in tailpipe emissions. When inhaled, these tiny particles are small enough to reach the bloodstream, causing inflammation. These particles can also bind with circulating volatile organic compounds and heavy metals prior to inhalation, leading to additional toxic substances in the body. As such, $PM_{2.5}$ affects almost every organ system, as shown in Figure 3. $PM_{2.5}$ exposure can lead to chronic obstructive pulmonary disease, small blood vessel disease, and can injure the myocardium leading to arrhythmias, atherosclerosis, and stroke (Li et al. 2020; Zhao et al. 2019; Du et al. 2016; Hayes et al. 2020). Chronic exposure to $PM_{2.5}$ poses the risk of cognitive decline, particularly among low-income groups where there is a higher likelihood of prenatal $PM_{2.5}$ exposure (Ke et al. 2023).

Particulate matter from non-tailpipe emissions (PM_{10}) is also dangerous to human health, despite being too large to enter the bloodstream. When inhaled, PM_{10} causes adverse inflammatory and pro-oxidant effects in the lungs and leads to acute responses like asthma and bronchitis (Fussell et al. 2022; Norbäck et al. 2019).

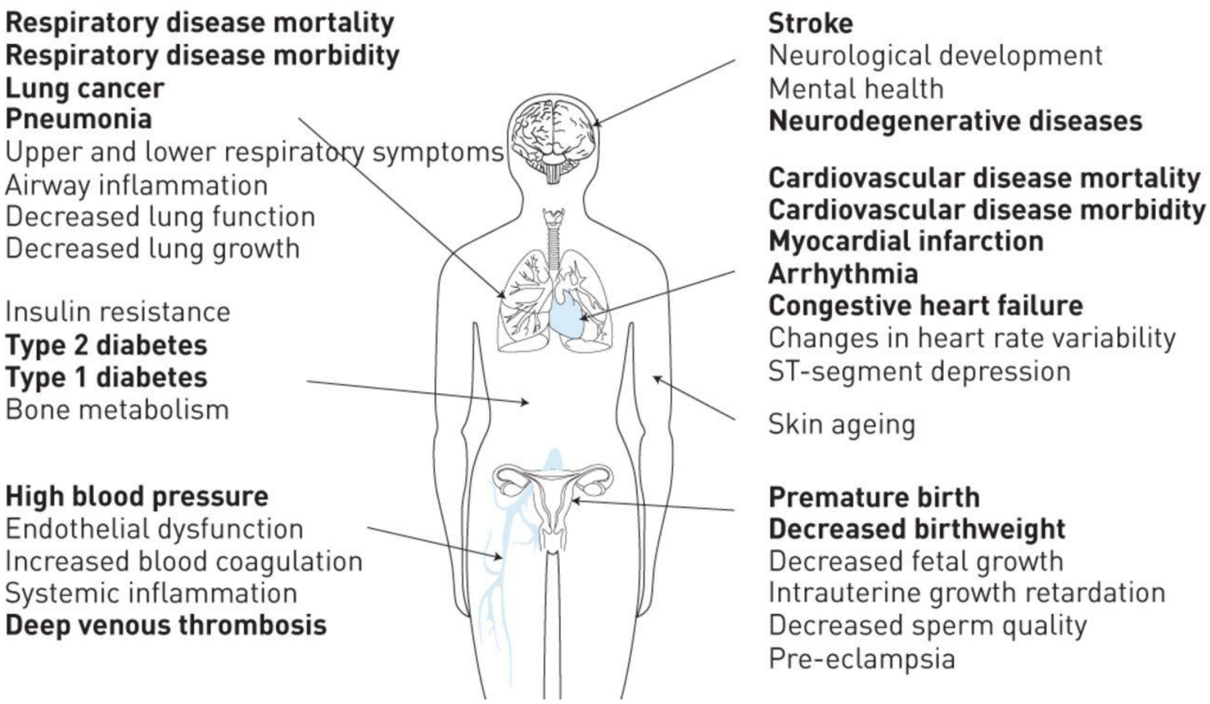

Figure 3. Health impacts associated with fine particulate matter. Causal associations are in bold. Thurston et al. 2017

Physical inactivity

Physical inactivity is a global public health challenge, partly due to urbanisation and increased use of passive modes of transport such as private motor vehicles (Brown et al. 2019). Australia is no exception – the majority of Australians do not meet the minimum recommendation of physical activity (AIHW 2023a). Australians are also highly reliant on passive modes of transport – less than 5% of commuters travel as a pedestrian or cyclist (ABS 2022).

Physical inactivity increases the risk of many diseases and is causally linked to the burden from type 2 diabetes, bowel cancer, dementia, coronary heart disease and strokes, as well as uterine and breast cancer in females. It is the ninth leading preventable cause of ill health and premature death (AIHW 2021). When combined with traffic congestion, physical inactivity is linked with poor mental health outcomes among motor vehicle users, including higher risk of depression, anxiety, stress, and low family cohesion (Penn et al. 2022).

Road trauma and injury

Car dependency also causes road trauma, the leading cause of injury mortality and morbidity globally. The over-reliance on private motor vehicles exposes children, pedestrians, and bicyclists to increased rates of road trauma, including premature deaths and significant injury and disability (WHO 2022).

Unfortunately, every year, thousands of Australians are hurt or die in road and other transport crashes, most commonly while in a car (AIHW 2023b). Despite Australia's goal to reduce road deaths and serious road injuries by 50 and 30% respectively, there has been no significant decline in the past decade. In fact, the rate of road injury increased by 11.3% over the decade to 2020.

In recent years, transport has been the cause of 11% of injury hospitalisations and 10% of injury deaths (AIHW 2023b):

- Car occupants have been involved in 31% of transport-related injury hospitalisations and 53% of transport-related injury deaths
- Motorcyclists have been involved in 25% of transport-related injury hospitalisations and 18% of transport-related injury deaths
- Pedal cyclists have been involved in 24% of transport-related injury hospitalisations and 3% of transport-related injury deaths
- Pedestrians have been involved in 6% of transport-related injury hospitalisations and 12% of transport-related injury deaths

Noise pollution

Road transport also contributes to mental and physical health issues associated with noise pollution. There is little Australian evidence available; however, the European Environment Agency estimates approximately 12,000 premature deaths could be attributed to traffic noise, plus a further 48,000 cases of ischaemic heart disease (EEA 2020).

The links between noise and stress are well established. The brain is always monitoring sounds for signs of danger, even during sleep. As a result, frequent or loud noise can trigger anxiety or stress. With continued exposure to noise pollution, a person's sensitivity to stress increases (Westman & Walters 1981). In recent decades, traffic noise pollution has been linked to elevated rates of dementia and Alzheimer's disease (Cantuaria et al. 2021). This effect could be due to sleep disturbance, stress hormone elevation and hence cardiac issues, inflammation and associated effects on the immune system.

Health and climate benefits of decarbonising the transport system

It's clear that Australia's transport system exacerbates public health challenges and the climate crisis, which in turn will have a further systemic effect on population health (WHO 2009).

The good news is, decarbonising our transport system will unlock a broad array of climate and health benefits. Below, we outline the climate and health benefits of low or zero carbon transport solutions, including electric vehicles, public transport, active transport and electric micromobility (e-bikes and e-scooters).

Cleaning up our tailpipes

The world is undergoing an accelerating transition to electric vehicles (EVs). Other alternative fuels such as hydrogen fuel cells are also being explored for some uses. The International Energy Agency has described the global transition to electric vehicles as a "sea change" and a "driving force" which will avoid the need for 5 million barrels of oil a day by 2030 (IEA, 2023) An electric vehicle generates no tailpipe emissions – neither greenhouse gas emissions nor air pollutants like $PM_{2.5}$, nitrogen dioxide and ground-level ozone. As such, replacing internal combustion engines vehicles with electric vehicles is a win-win solution for tackling climate change via decarbonisation and improving health via reduced air pollution (Pan et al. 2023). Non-tailpipe related air pollution remains an issue with EVs.

Electric vehicles are much quieter than ICE vehicles, which is also beneficial when considering the health impacts of noise pollution. However, silent cars can be dangerous to those with vision impairment. Unlike America, Europe and parts of Asia, Australia does not currently require electric vehicles to generate sound. The Australian Government is deciding whether to make it mandatory for electric vehicles to be fitted with an Acoustic Vehicle Alerting System (AVAS) to make it easier for pedestrians to detect them. Vision Australia asserts that 'if mandated, the AVAS could save lives and avoid thousands of injuries" (2023). The Australasian College of Road Safety estimates that AVAS in Australia 'could potentially prevent over 3,400 crashes by 2050' (Lawrence et al. 2020).

Not a silver bullet

While the health benefits of converting the fleet to electric vehicles are substantial, widespread uptake will not address many of the entrenched health effects of a car-dependent transport system.

Many of the negative health effects of our current transport system derive from the impact of car dependency and urban design. Moving from ICE vehicles to electric vehicles will have limited benefits when it comes to addressing physical inactivity, road trauma and traffic congestion (Penn et al. 2022).

Electric vehicles may also have some unintended consequences, in addition to the risks associated with silent cars outlined above. For instance, the reduced impact on the environment and the reduced per-kilometre driving costs may result in increased private vehicle kilometres travelled, leading to increased levels of physical inactivity, at a personal health level (Penn et al. 2022).

Electric vehicles have no tailpipe greenhouse gas emissions. In countries where fossil fuels are involved in electricity generation, all electricity use can to some extent be associated with greenhouse gas emissions and air pollution. The overall picture is complex and situation specific; electric vehicle batteries can, for example, potentially also help smooth peaks in electricity demand (International Energy Agency 2020, Needell et al 2023).

There are also greenhouse gas emissions associated with the production of electric vehicles, and the mining of raw materials used in their production, as there are with ICE vehicles. Disposal of all vehicle types remains an ongoing issue. At present there are few options for reusing or recycling used electric vehicle batteries, potentially creating a further downstream effect on the environment (Slowik et al. 2020).

Widespread electric vehicle uptake also has implications for health equity. The transition to EVs will not in itself contribute towards improving equity in access and mobility equity (which is tightly linked to public health). Given that lower-income communities tend to face transport disadvantage – and that people unable to operate or afford private motor vehicles may be reliant on public and active transport – it is crucial that transport policy prioritises infrastructure for active and public transport without relying on electric vehicles to meet the mobility needs of all populations (Penn et al. 2022).

Making public transport clean and accessible

Investment in public transport infrastructure reduces carbon emissions and air pollution while increasing physical activity – providing measurable health co-benefits in terms of mortality and disability adjusted life years (Kwan et al. 2017; Brown et al. 2019).

The health benefits are broadly achieved through three main shifts:

- A modal shift from commutes via private car to commuting via shared transport
- Reducing air pollution emitted by public transport by switching from fossil-fuelled vehicles to electric vehicles
- Increasing physical activity during a public transport journey when compared to door-to-door trips in a private motor vehicle.

Modal shift

People switching from private motor vehicles to public transport reduces air pollution, CO2 emissions, congestion, personal stress and infrastructure strain. To maximise these benefits, various policies can be implemented to limit motor vehicles in areas of good public transport coverage (Kwan et al. 2017; Butler et al. 2022). For example, London, Singapore, Stockholm and Milan have all introduced congestion pricing systems, where drivers are charged to use certain roads in order to reduce traffic congestion and emissions (Vosough et al. 2020; Hosford et al. 2021). Vosough et al. (2020) note that congestion pricing may reduce car trips, air pollution, asthma attacks, and road traffic injury. Drivers may decide to either change their routes or switch to public transport (Hosford et al. 2021). Tolls can also respond to the level of pollution emitted by an individual vehicle.

Overcoming unpopular policy: Congestion charging in Stockholm, Sweden
In Stockholm, congestion charging was introduced as a trial for six months in 2006. To garner support for an unpopular policy, the city officials delivered extensions to the public transport system at the same time. Following the six-month trial, there was overwhelming support for the congestion charge. The change in public opinion arose as a consequence of the significant improvements in travel time observed during the trial (Eliasson et al. 2009). Not only did the charge reduce congestion, but the policy also led to a 4.5% increase in public transport patronage . Importantly, the health co-benefits were considerable, with levels of CO_2 decreasing by 2.7%, nitrogen oxides decreasing by up to 8.5%, and road traffic injury decreasing by between 5 and 10% (Eliasson et al. 2009).

Electrifying public transport

As with electric vehicles, electrifying our buses, trams and trains will result in less transport-related air pollution and thus reduce the burden of associated morbidity. For instance, transitioning from fossil fuel-powered buses to electric buses delivers the same health co-benefits of private EV uptake, even faster (Gopinath et al. 2022; Ribeiro and Mendes 2022).

Increasing physical activity

Unlike private motor vehicles, which offer users door-to-door motorised independent mobility, public transport usually requires users to walk for access/egress to shared routes. Public transport use also supports additional walking around and between intermediate destinations during the day, as users are separated from their vehicle at home or point of access. Evidence suggests that public transport users have up to four times greater odds of meeting physical activity recommendations and walk up to 33 min more per day compared to private motor vehicle users (Brown et al. 2019). Improving accessibility to public transport will improve population health by facilitating physical activity and lead to healthcare cost savings compared with business-as-usual. These wider health benefits should be better considered in transport planning and policy decisions (Brown et al. 2019).

Solutions outside of our urban centres

Australian urban residents tend to have favourable views towards public transport, particularly in inner city areas with good coverage. But beyond our urbanised cities, the lack of extensive public transport coverage means that residents remain dependent on private motor vehicles (Butler et al. 2022). On-demand transit is a flexible and responsive transport solution with enormous potential to reduce car dependency in low density suburban, peri-urban and rural environments with limited public transport access (Nelson and Caulfield 2022). On-demand transit provides customers with shared transport services (usually a small bus) at a cost similar to public transport. If the vehicle is electric, this additionally reduces the emissions per kilometre travelled.

In these environments, transport policy aimed at supporting lower car dependence can focus on using on-demand transit to expand existing transport services. This can be achieved through strategies that target commuters with multi-leg journeys, such as people who drive to train stations, by encouraging them to replace driving with shared or active transport for the first or last leg of their trips (Butler et al. 2022).

Active transport and urban planning

The shift to electrified transport is necessary but not in itself sufficient to create a healthy and equitable low emissions transport system. Many more health benefits can be unlocked by a more holistic shift from a car-dependent transport system to one which incentivises walking and cycling ('active transport').

Replacing car trips with cycling or walking has been found to meaningfully increase physical activity levels, significantly reduce the risks of premature mortality and morbidity from obesity, cardiovascular disease, type 2 diabetes, dementia, ischaemic heart disease, cerebrovascular disease, osteoporosis, cancers, and other non-communicable diseases associated with inactive lifestyles (Penn et al. 2022; Jarrett et al. 2012; Haque et al. 2022; Allirani et al. 2022; Rojas-Rueda et al. 2016; Ferrari et al. 2022).

One study of longitudinal data from seven European cities underscored both the physical and mental health improvements associated with active transport (Avila-Palencia et al. 2018). Active transport users reported higher self-perceived health and mental health than those using passive modes like cars or motorbikes. Cycling was associated with good self-perceived health and mental health measures like vitality, and fewer feelings of loneliness. Walking was associated with good self-perceived health, higher vitality, and more frequent contact with friends and family (Avila-Palencia et al. 2018).

However, shifting people from passive to active transport must be accompanied by appropriate urban infrastructure to ensure the safety of cyclists and pedestrians. Perceived unsafety is a key barrier to cycling, which can be overcome by separated and safe cycling infrastructure (Marshall and Ferenchak 2019; Useche et al. 2019). Cyclists and pedestrians travelling greater distances on roads designed solely for vehicles can lead to an increase in road traffic injury (Stevenson et al. 2016).

New urban mobility: transitioning to a decarbonised transport system in London, England
London was one of the first cities to introduce congestion charges to mitigate traffic-related air pollution. Since 2003, the city has introduced further innovations focused on reducing private motor vehicle use. The innovations include policies imposing charges for diesel-fuelled vehicles driven in the city, and designing suburban areas to reduce through traffic and hence create 'low-traffic neighbourhoods'. These policies have resulted in an increase in city residents cycling and using public transport. The mode shift arising due to these policies has been phenomenal, with the inner London suburb of Lambeth experiencing 25,000 fewer car trips a day since low-traffic neighbourhoods were introduced in 2020 (this accounts for the decline in trips observed due to COVID) and a 40% increase in cycling, walking and e-scooter trips (Kersley 2022).

Electric micromobility

Electric micromobility (EMM) – like e-scooters, e-bikes and e-mopeds – is a new technology sector which launched globally in 2017. EMM is carbon positive compared with same-distance trips by fossil-fuelled transport (Hollingsworth 2019; Moreau 2020; De Bortoli 2021; Kazmaier et al. 2020; EYGM Limited 2020). Other benefits of EMM include:

- Reduced congestion
- More efficient transport for shorter trips (CB Insights 2020)
- Improved access to public transport (Fearnley 2020; Yanocha & Allan 2021; ITF 2021; Hollingsworth 2019; Reed 2019)
- Increased physical activity (NABSA 2020; Lopez-Doriga 2022; Severengiz 2020)
- Reduced need for parking space (NABSA 2020; Severengiz 2020; Reed 2019)

Health benefits

EMM provides the physical and mental health benefits associated with moderate levels of activity, particularly in those who are physically inactive (Anderson et al. 2022; López-Dóriga 2022; Berntsen et al. 2017). One study on overweight or obese individuals living in regional Australia found that e-bikes provided a moderate level of physical activity and self-perceived improvements in physical and mental wellbeing (Anderson et al. 2022). These findings align with those of the Lobben et al. (2018) Norwegian study, which found that previously inactive participants who began using e-bikes experienced lower blood pressure and heart rates – similar to the benefits of conventional cycling. The Bourne et al. (2018) review of 17 studies provided moderate evidence that e-bikes can improve cardiorespiratory fitness in physically inactive individuals, and thus offer an alternative to conventional cycling.

The physical and mental health benefits of taking up EMM vary with the specific mode shift (López-Dóriga et al. 2022):

- Shifting from private motor vehicles and motorcycles to EMM decreased the risk of anxiety, depression, and stroke.
- Shifting from public transport to e-bikes and e-scooters also had health benefits, whereas shifting to e-mopeds posed health and safety risks
- Shifts to e-bikes providing the greatest health gains, followed by e-scooters and then e-mopeds

Climate benefits

Shifting from ICE vehicles and motorbikes to EMM can result in reduced emissions (López-Dóriga et al. 2022). To maximise decarbonisation efforts, EMM modes should complement existing public transport networks and be tailored for moderate-distance trips (Felipe-Falgas et al. 2022)

Strategies to incorporate EMM may also depend on the composition of transport modes in cities. A move from private motor vehicles to EMM in cities with poor public transport infrastructure and a high reliance on private motor vehicle use, such as in Australia, will likely produce more environmental and health benefits than in cities with higher proportions of active transport use (Felipe-Falgas et al. 2022). Furthermore, cities using electric grids dependent on fossil fuels may also benefit from a modal shift to EMM, as the electricity consumption of EMM per passenger is lower than that of trains, for example (Felipe-Falgas et al. 2022).

Road trauma

As with active transport solutions, EMM can lead to increased road trauma in the absence of safe infrastructure. Hence considerable investment in safe infrastructure for EMM and active transport users is required to deliver low, or preferably no, road trauma (Stevenson et al. 2016).

Invest in transport equity

In areas with low public transport coverage, people unable to operate or afford private motor vehicles are more vulnerable to social and economic exclusion (Butler et al. 2022). Recent transport surveys indicate that the poorest and most socially disadvantaged members of society also experience transport disadvantage (Lucas 2012), spending large proportions of their income and time on driving.

In Australia, young people, the elderly, low-income households, and First Nations populations in regional areas tend to experience the greatest barriers to transport. This limits access to work opportunities, education, and social activities (Johnson 2011; Hurni 2006; Altman and Hinkson 2007; Lucas 2012). Investment in measures that promote health, reduce emissions and improve transport equity is critical to allow people to access essential services and to provide health co-benefits (Lucas 2012).

Success stories

While this paper has outlined the significant challenges in decarbonisation of the transport system, there are many national and international success stories where inspiration and learning can be drawn from in order to improve climate and health outcomes.

Facilitating electric micromobility in Brisbane, Australia

Brisbane has been a pioneer in the adoption of electric micromobility (EMM), serving as the first major city in Australia to introduce an e-scooter sharing scheme in 2018 (Brisbane City Council 2021). The program deployed 2,800 e-scooters and e-bikes, and since their inception has logged more than 4.5 million rides. At an average of 2.2 km per trip reported by Neuron Mobility, an EMM operator, between November 2018 and May 2021, total emission reductions were around 1,000 tonnes of CO2 equivalent (CO2-e) (Neuron Mobility 2022). The benefits from EMM also include reduced congestion, improved tourism experience, and improved access to services.

EMM has also led to considerable economic benefits. Neuron, an EMM operator, highlighted that in the 2020–21 financial year, their operations contributed $116.6 million in direct, indirect, and enabled economic activity towards Brisbane's economy, and is estimated to have created and supported 681 Brisbane-based jobs (Neuron Mobility 2022).

As Brisbane's strategy notes, the sustainability credentials of EMM are increasingly evident. The strategy notes that between '30-50% of riders report using e-scooters to replace car rides on their most recent trip', and that 'in younger demographics (under 40), car ownership is a decreasing priority… car sales are down year on year' (Brisbane City Council 2021). Improvements in sustainability have been estimated from the level of mode shift affected by more sustainable transport modes in the first years since EMM was launched (Hollingsworth 2019; Moreau 2020). Research shows that EMM encourages public transport participation by solving first and last-mile connectivity issues and reduces longer-term private car ownership.

Shifting to active travel in Paris, France

In Paris, France, investments in active travel, particularly in cycling networks, prompted a sharp increase in cycling levels (Xiao et al. 2022; Buehler et al. 2022), leading to better health and climate outcomes.

As the most densely populated city in France, the city expanded its total cycling network from only 5 km in 1995 to over 1,000 km (Buehler et al. 2022; Xiao et al. 2022). Over the past 25 years, the city actively promoted bike-sharing systems like Vélib', comprising over 20,000 bicycles, making it one of the largest bike-sharing systems in the world (Buehler et al. 2022). Paris' expansive cycling network consists not only of on-street bicycle lanes – including 170 km of protected bi-directional lanes – but also over 80 km of off-street cycling paths (Buehler et al. 2022). As a result of these expansions to the cycling network, Paris has observed a significant increase in cycling levels over 24 years, increasing by 60% from 1997–2004 and then by 250% from 2004–19 (Buehler et al. 2022).

In addition to improvements in cycling infrastructure, micromobility was also supported, while private motor vehicle travel was disincentivised. Paris provided financial incentives for the purchase of e-bikes and e-cargo bikes, paying one-third of the purchase price for 85,000 bicycles between 2009–22 (Buehler et al. 2022). Moreover, the city discouraged private motor vehicle use by increasing car parking costs, removing parking spaces, converting car lanes into bus-priority lanes, and banning motor vehicles entirely from roadways running along the Seine River, which flows through central Paris (Buehler et al. 2021; Buehler et al. 2022).

Paris' extensive investment in active transport infrastructure illustrates key lessons to be learned by other cities looking to promote modal shifts from passive to active transport. Expanding cycling lanes while ensuring that they remain protected from motorised vehicles is crucial for ensuring increases in ridership. Investments in cycling lanes can go hand in hand with promotion of micromobility modes, like e-bikes, as well as bike-sharing systems like Vélib'. Such investments will be more fruitful when accompanied by disincentives for car use.

Retrofitting the built environment in Barcelona, Spain

The Barcelona Superblock trial illustrates what can be achieved when retrofitting built form to restrict motor vehicle access in high-density locations. In this trial, researchers and local government retrofitted the urban design and planning principles of three 'superblocks'. Large superblocks covering an area of around 400 m by 400 m were created from residential blocks of 150 m by 150 m. The residential blocks were surrounded by normal busy streets. Outside the superblocks, the city's normal through traffic was accommodated on streets with a maximum speed of 50 km/h. Within the superblocks, cars were banned or restricted to 20 km/h, priority was given to walking and cycling, and open space was reclaimed or created from parking (Figure 6).

An evaluation of these three superblocks and the resultant extrapolation of the findings to the entire city of Barcelona (it is feasible to retrofit all blocks to superblocks) found premature mortality rates were reduced by 700 deaths a year, and life expectancy increased. This was due to reductions in air pollution, noise and heat, greater access to green space, and increased transport-related physical activity. The economic effects of transforming the existing urban blocks were estimated at €1.7 billion (A$2.7 billion) a year. This benefit mainly comes from increased life expectancy, a 20% reduction in premature mortality, and a 13% reduction in overall burden of disease (Mueller et al. 2019).

How to realise the co-benefits of transport decarbonisation

The science is clear. Without rapid, ambitious and decisive action to reduce the level of CO2 in our atmosphere, the world as we know it will be altered irrevocably and human health will suffer. Some level of warming is already "locked in"; this means we must take action in every sector and for all people in Australia if we are to be prepared for the reality of living on a warming planet. This paper has demonstrated the enormous opportunity to improve health and equity while transforming the transport sector.

Australia's road transport system relies heavily on private motor vehicles, exacerbating emissions load and associated health harms. Australia's per capita transport emissions are higher than those of most other countries due to our inefficient road passenger, rail, and bus transport systems. The over-reliance on a transport system powered by fossil fuels has resulted in harm to people's health and the environment. There is an urgency to transition from a 20th-century fossil-fuelled transport system to a zero-emission system involving electric vehicles with safe infrastructure for increased use of active and public transport systems.

The sprawling residential-only development patterns that dominate most suburban areas in Australian cities limit the ability of children and adults to walk or cycle for their daily travel requirements. Low-density housing in peri-urban areas also renders public transport costs prohibitive, externalising transport costs through forced car ownership. This leads to exposure to health risks associated with traffic speed and volume, vehicle emissions, noise pollution, and physical inactivity.

The good news is that there are overwhelming health co-benefits associated with transitioning from private motor vehicle use to active and public transport. Several studies highlighted in our paper show the considerable gains in disability-adjusted life years associated with such a transition. Similarly, transitioning from private motor vehicles to EMM – especially if shared – can result in health co-benefits while reducing emissions. Mode shifts to active transport will provide the greatest health gains, while EMM (particularly e-bikes) will deliver health co-benefits akin to those arising from moderate levels of physical activity.

A transport policy that supports the uptake of electric vehicles for public transport will result in an array of health co-benefits while dramatically decarbonising our transport system. However, a focus solely on private electric vehicles is unlikely to deliver deep decarbonisation and may marginalise many Australians.

Young Australians, the elderly, low-income households, and First Nations populations in regional areas experience the greatest barriers to transport, limiting access to work opportunities, education, healthcare, and social activities. Investment in transport equity – providing safe and affordable modes of travel that all groups of a population can access – is critical for allowing users to access essential services and to provide associated health co-benefits.

Merely advocating for an electric vehicle policy will not address the transport equity crisis experienced across many regional and peri-urban areas. A comprehensive combination of interventions, including those highlighted in this review, is needed.

Despite the challenge ahead, this review highlights important strategies that will achieve reductions in road transport-related carbon emissions and deliver health co-benefits. Alongside electrification, these strategies need to include:

- increased investment in safe, accessible and reliable electric public transport
- implementing safe infrastructure for increasing walking, cycling and EMM transport
- safely deploying shared EMM transport in cities, with an emphasis on supporting “last mile alternatives” to private vehicles.
- advocating for 15–20-minute communities within cities and towns, thereby supporting a city of short distances and increased access to amenities using active, public and EMM transport
- developing transport policies that incentivise active, public and EMM transport (examples could include congestion charging, removal of street parking, low emission zones, which have been beyond the scope of this review)
- ensuring transport equity, which is integral to a healthy decarbonised transport future.

No single intervention will achieve the transformation required to attain a decarbonised transport system that also promotes health and wellbeing. Australia has significant challenges in achieving decarbonised transport, in part because of its dependency on private motor vehicles. However, with decisive leadership at all levels of government, significantly positive outcomes for our climate and our health can be realised.

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