Policy Responses of Australian Governments to the Health Consequences of Greenhouse Gas and Brown Pollution in the Urban Planning, Environment, and Energy Sectors.

Michael Patrick McGreevy (michael.mcgreevy@flinders.edu.au)
Flinders University https://orcid.org/0000-0002-6160-5252

Fran Baum
Flinders University

patrick Harris
University of New South Wales

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Abstract

Greenhouse gas and brown pollution from urban land uses, transport, infrastructure, and energy generation harms population health and health equity. This article reports on an standard document analysis of policies from the urban planning (land use, transport, infrastructure, housing), energy, and environment sectors of Australian state, territory, and federal governments and their responses to the health and health equity implications of greenhouse gas and brown pollution from their sector. Our analysis shows there is awareness in all jurisdictions and sectors of their contribution to greenhouse gas pollution but significantly less when it comes to brown pollution. It also shows that commitment to action on reducing pollution varies between jurisdictions and between sectors within jurisdictions. In conclusion, Australia could do significantly more to reduce the health harms from urban pollution through more innovative and coordinated policy responses across jurisdictions and sectors.

1. Introduction

The World Health Organization has identified urban pollution as a major threat to health (WHO, 2013). This article explores the policy responses to the health and health equity challenges of pollution by Australian federal, state, and territory governments in the urban planning (land use, transport, infrastructure & housing) and energy (electricity and gas) sectors as major contributors to urban pollution; and the environment sector as a sector directly and indirectly affected by the outputs of the other two.

1.1 Greenhouse gas and brown pollution in Australia

The urban planning and energy sectors contribute significantly to the degradation of the environment and human health via the release of greenhouse gas (GHG) pollution and ‘brown’ pollution. GHG pollution causes dangerous climate change (Wu et al., 2016, Bellard et al., 2012, Costello et al., 2009). Brown pollution, consisting of localised concentrations of Nitrogen oxides (NOs) Volatile organic compounds (VOCs), particulates, ozone and peroxyacetyl nitrate (PAN), adversely affects air, water, and soil quality (Zhang and Batterman, 2013, Karner et al., 2010).

In Australia, a substantial amount of GHG and brown pollution is the result of burning fossil fuels for transport and electricity. Australia generates most of its electricity from burning coal, often in aging plants (Connor et al., 2004, Higginbotham et al., 2010) AER, 2019). Furthermore, Australia has the largest houses in the world and buildings in general are often poorly insulated and sealed due to a legacy of many decades of relatively inexpensive energy (Moore et al., 2019, Clune et al., 2012). There are also substantial links between the city, its buildings, infrastructure, and transport systems and average per capita consumption of petrol (Newman and Kenworthy, 1989, McIntosh et al., 2014). McIntosh et al. (2014) show Australian urban residents are some of the highest consumers of petrol per capita in the world due to the comparatively low residential densities and the automobile oriented form of the urban

environments where they live, work, consume, and recreate. Compounding the problem Australia has the most energy inefficient motor vehicle fleet in the OECD (Smit, 2019).

As a result of these inefficiencies, Australian has the second highest levels of GHG pollution per capita in the world (Union of Concerned Scientists, 2020). Furthermore, Australia's recent GHG emission levels are at best steady. Pollution from electricity generation has been falling, however, emissions from transport continue to rise (DISER, 2019).

1.2 Article context and structure

This article analyses Australian urban planning, energy, and environment policies in order to ascertain to the position they present on the problems of brown and GHG pollution. Scholars have noted that integrating climate-change friendly environmental policies into the policies of other sectors such as energy and urban planning are a major challenge in Australia because of a high reliance on fossil fuels for domestic energy supplies and their major contribution to exports (Byrnes et al., 2013, Cheung and Davies, 2017, Ayling, 2017, Hobbs and Swiatek, 2019).

Our findings and analysis are part of broader research which has examined how whole-of-government action can be used to promote health while still addressing sector-specific goals. This article looks specifically at policy responses of Australian federal (Commonwealth of Australia), state (New South Wales [NSW], Victoria [Vic], Queensland [Qld], Western Australia [WA], South Australia [SA] and Tasmania [Tas]) and territory (Australian Capital Territory [ACT] & Northern Territory [NT]) governments to urban pollution as a determinant of health and health equity.

The following section reviews literature on the links between pollution and population health and health equity. Section three outlines the research methods used to generate the data for this study. Section four presents the results based on the data gathered and section five discusses the findings. Section 6 concludes and considers potential policy responses.

2. Background

2.1 Pollution and Health

The health effects of both GHG emissions and brown pollution are well known (Wu et al., 2016, Bellard et al., 2012, Costello et al., 2009, Zhang and Batterman, 2013, Karner et al., 2010). GHG pollution and the climate change it causes threatens the long-term health and survival of humans, other species, and ecosystems (Bellard et al., 2012, Costello et al., 2009). Brown pollution elevates and exacerbates risks from asthma, pulmonary disease, cardiovascular events such as respiratory complaints, lung disease and heart attacks, diabetes premature mortality adverse birth outcomes such as low weight and prematurity, and dementia, while some chemical pollutants such as benzene are known carcinogens (Chen et al., 2017, Kim et al., 2015, Zhang and Batterman, 2013, Oakes et al., 2016, Maria Costantini, 2010, Anthony Seaton, 1995, Marshall et al., 2009). Brown pollution has also been shown to exacerbate negative effects

from severe acute respiratory syndromes caused by viruses such as Covid 19 (Travaglio et al., 2020, Wu et al. 2020). The WHO (2013) estimates brown air pollution caused approximately 4.2 million deaths across the world in 2016. In Australia it is estimated brown pollution causes 2400-3000 premature deaths, not including cancers, and costs the economy between $7.7 billion and $ 17.8 billion per annum (Schofield, 2017).

A major contributor to both GHG pollution and brown pollution in urban environments are the internal combustion engines of private cars, buses, and commercial vehicles (Zhang and Batterman, 2013, Karner et al., 2010, Kim et al., 2015). In addition, particulates from exhausts as well as brakes tyres and general mechanical wear produce road dust with a complex physiochemical nature that elevates its toxicity (Oakes et al., 2016). Road dust contributes directly to air pollution but also settles upon hard surfaces such as roads, carparks and rooves from which it is eventually washed into watercourses, water bodies, ground water, and natural ecosystems, adversely affecting their ecological health (Oakes et al., 2016).

The contribution electricity generation makes to GHG and brown pollution depends upon the resources used. There are resources such as wind and solar which produce little in the way of GHG or brown pollution, and resources such as coal and liquid fuels which produce GHG as well as brown pollution similar in makeup and effect to that produced by the internal combustion engines of motor vehicles (Connor et al., 2004, Higginbotham et al., 2010, Bridges et al., 2015, Markandya et al., 2009, Pope III et al., 2009). There is also natural gas which produces around half the level of GHG pollution of coal and comparatively low levels of brown pollution (Union of Concerned Scientists 2014, EIA, 2016).

Coal burning and its mining and transportation also produces and spreads environmental and health worsening coal dust across rural and urban landscapes. Coal mining and burning uses large amounts of water which pollutes surface water and aquifers. In addition, pollution from the mining, burning and transport of coal degrades landscapes (Connor et al., 2004). On the other hand, natural gas mining releases methane a powerful GHG and has been known to contaminate ground water (Union of Concerned Scientists 2014).

2.2 Green environments and pollution mitigation

‘Green’ urban environments in riparian corridors, parks, reserves, buffers, land inappropriate for development, cemeteries, verges and private allotments can provide *urban ecosystem services* (UES) which directly mitigate the effects of pollution via water and air filtration and absorption, noise abatement, and microclimate moderation (Larondelle and Haase, 2013, Gómez-Baggethun and Barton, 2013). They also can provide habitats for wildlife, soil formation, bio-diversity refuges, and pollination, as well as views, cultural and spiritual pleasures and recreational opportunities which benefit both physical and mental health for nearby residents (Breuste, et al. 2013, Larondelle and Haase, 2013). However, urban, and peri-urban greenspaces and ecosystems are easily degraded by pollution or lost to urban development, resulting in the loss or reduction of UES with effects on the physical and mental health and wellbeing of urban residents (Breuste, et al. 2013).

2.3 Pollution and Health Equity

The effects of both GHG and brown pollution are also not shared equally. It is likely those contributing most to greenhouse gas pollution will be the least affected by it because wealth enables people to both consume more and mitigate effects better (Barbier and Hochard, 2018, Costello et al., 2009). In addition, fossil fuel driven consumption of people today is inequitable for future generations (Skillington, 2019, Diprose et al., 2019). In a metropolitan area brown pollution is found in highest concentrations within 150 metres and up to 500 metres of congested or busy arterial roads, urban freeways, intersections, suburban shopping centres and central business districts (CBD) (Zhang and Batterman, 2013, Schweitzer and Zhou, 2010, Zhao and Li, 2017, Oakes et al., 2016, Hankey et al., 2017, Marshall et al., 2009). The health effects of prolonged exposure to brown pollution are most pronounced for people who live, work or study close to such areas of concentration. They are similarly acute for those who spend long periods of their days commuting or working in congested traffic (Zhang and Batterman, 2013, Karner et al., 2010, Marshall et al., 2005).

The effects of brown pollution from coal mining and generation also vary due to proximity. The risk from premature death or sickness from the burning of coal is estimated to be 3 to 4 times higher for people living within 50 km of a coal generator (Connor et al., 2004, Higginbotham et al., 2010).

2.4 Pollution and sustainable energy transition planning

Reducing GHG and brown pollution in the energy and urban planning sectors requires an expedited socio-technical sustainable energy transition (SET) from fossil fuels to renewables in supply (Hess, 2014, Rogge et al., 2017, Köhler et al., 2019, Markard et al., 2012). It also requires demand reduction via more energy efficient buildings, appliances, and machinery.

In the transport sector, pollution is reduced by a transition towards more energy efficient and cleaner private, commercial, and public transport vehicles. It is also reduced by reductions in vehicle kilometres travelled (VKT), achieved by transferring short car journeys to active transport (walking, cycling wheelchairs), and medium and long trips to cycling and/or combined trips of walking and public transport (Newman and Kenworthy, 2015, Stevenson et al., 2016). Increases in public transport and cycling occur when comprehensive, safe, and convenient networked infrastructure and services are in place. Increases in active transport are observable when residents live in pedestrian oriented and mixed use ‘liveable’ neighbourhoods where they are able to easily make multiple discretionary (nonwork) trips on foot (Hooper et al., 2015, Handy and Clifton, 2001).

3. Methods

This paper draws on data from a census of policy documents undertaken as part of broader Australian Reserch Council funded research in 2017. In total 221 policy documents were analysed for this paper; 178 from the environment sector, 108 from urban planning, and 142 from energy (Authors, 2018).

3.1 Thematic document analysis

We used standard document analysis techniques, which involved collecting, coding, synthesising and theorising the research data (Corbin and Strauss, 2008, Liamputtong and Ezzy, 2006). A detailed coding framework (Authors, 2018) was used, In terms of the analysis, we considered policies for the extent to which they focused upon health and health equity within policy domains. For this paper alone, documents were also searched for specific mentions of GHG and/or brown pollution, renewables, and environmental sustainability. Any mentions of these were analysed under the original framework i.e. their relationships to determinants of health and health equity.

4. Results

This section presents the results of the document analysis concerning the extent to which energy (electricity and gas) , urban planning (land use, transport, housing and infrastructure and environment sector policies in Australian state, territory and federal jurisdictions recognise and respond to the health-related implications of GHG or brown pollution. This includes direct relationships within goals, objectives, strategies, and evidence; as well as policies that research show have implications for increases or decreases in exposure to health effecting pollution.

4.1 Policy overview

Environmental sustainability is included as a principal goal in all jurisdictions and within policy documents in all sectors. GHG pollution reduction is the principal focus, whereas the effects of brown pollution are downplayed or silences. Correspondingly, all jurisdictions have objectives to reduce GHG pollution, but none have targets to reduce brown pollution.

Evidence of the links between GHG pollution and climate change are commonly referred to in documents from all three sectors in all jurisdictions. For example, this evidence from the ACT makes the link clear.

the way we produce and consume energy now is unsustainable. There is credible science and observable evidence indicating that human-induced greenhouse gas emissions are polluting the earth's atmosphere and leading to dangerous and irreversible climate change. Burning fossil fuels is a major contributor to those climatic changes.

However, evidence of the links between climate change, health, and health equity are rarely mentioned as a justification for policies. The only link mentioned is the potential for climate change to increase death and injury from increases in the frequency and severity of natural disasters.

The energy sector pays much greater attention to GHG pollution reduction than does the transport sector. Nationally, the federal government has a target of reducing GHG pollution by 26-28 per cent of 2005 levels by 2030 as part of the Paris Agreement (DISER, 2020). The major mechanism for this reduction has been a federal renewable energy target (RET) which obliges electricity retailers to purchase 20% (33,000 gigawatt hours) of their electricity from renewable resources by 2020 using tradeable renewable energy

certificates (REC) issued by the federal government (Hua et al., 2016, Carley, 2009). There are no similar targets or mechanisms to reduce emissions from transport.

Brown pollution is recognised as a health problem in environment sector documents from all jurisdictions. However, there are no mentions of brown pollution as a health problem in any energy sector document in any jurisdiction. Evidence of the links between brown pollution and health are mentioned in urban planning documents from all jurisdictions other than SA and NT. The most comprehensive evidence-based assessment of the health implications of brown pollution from motor vehicles comes from the NSW environment department via the relatively old *Cleaner Vehicles and Fuels Strategy*. It states:

The health costs of air pollution in NSW are substantial. Although Sydney has good air quality by world standards, a reduction in current air pollution levels would continue to improve the population's health in the long-term. The estimated annual health cost of current levels of air pollution in the greater metropolitan area is $4.7 billion, or $893 per head of population. Health experts estimate that air pollution causes between 640 and 1400 deaths per year in Sydney, and between 900 and 2000 hospital admissions for respiratory and cardiovascular illnesses (DECC, 2008).

Despite the comprehensive assessment of the problems of brown pollution in this excerpt, actual strategies in the document to tackle brown pollution from motor vehicles are modest. In addition, The comprehensive evidence provided in and throughout the NSW *Cleaner Vehicles and Fuels Strategy* are not repeated in subsequent NSW land use or transport sector plans. *For example, the Plan for Growing Sydney* refers to the health effects of pollution in a less forthright manner.

Urban development has implications for air quality, with exposure to air pollution associated with the incidence of respiratory problems, heart and lung disease and risks to children and the elderly. Through urban layout, we can improve air quality in residential areas to improve our health and wellbeing (DPE, 2014).

In other jurisdictions the specific relationships between health and brown pollution in urban planning documents are silences or when mentioned downplayed as a current health problem, for example:

In the coming decades, it will become more important to manage pollution so that it does not exceed the environment's capacity to absorb it. Melbourne's air quality compares well with cities worldwide but there are occasional days of poor air quality (DELWP, 2014).

Perth and Peel, like most urban areas in Australia, experience occasional episodes of poor air quality (WAPC, 2010).

4.2 Pollution and energy sector policies

The state and territory jurisdictions of Qld, SA, and the ACT also have key performance indicator (KPI) renewable energy targets. The SA government's target goes well beyond the modest federal government

target with an objective to:

achieve $10 billion of investment in low carbon energy generation by 2025 and we want 50 per cent of our electricity production to be by renewable energy by 2025 (RenewablesSA, 2015).

Other jurisdictions have more ambiguous objectives such as this from WA:

By 2031, a significant and continually growing proportion of Western Australia's energy needs will be met from renewable energy sources (Department of Finance, 2012).

In NSW the state policy reflected the national target with the added objective of affordability:

This NSW Renewable Energy Action Plan supports the achievement of the national target of 20% renewable energy by 2020. The Plan positions NSW to increase the use of energy from renewable sources at least cost to the energy customer and with maximum benefits to NSW (Office of Environment and Heritage, 2014).

While all jurisdictions have targets to increase renewable energy generation, of the four states which currently burn coal for electricity generation, only Victoria has a strategy to exit from coal:

Develop policy mechanisms within 0-5 years for innovation or exit of brown coal energy generation to provide clearer signals and certainty to industry and the community and contribute to reduction targets for greenhouse gas emissions (Infrastructure Victoria, 2016).

In NSW, WA, Qld (states with major fossil fuel export industries) and federally the need to exit from fossil fuels as part of a sustainability transition is either a silence or contradicted by other policies such as these from Queensland and Western Australia:

Unlocking untapped coal reserves in the Galilee Basin will have significant economic benefits for centres such as Rockhampton, Mackay, Bowen and Townsville (DILGP 2016).

Coal will continue to supply Western Australia's electricity generation portfolio in conjunction with emissions reduction technologies (Government of WA 2012).

4.3 Pollution and the Urban Planning and Transport Sectors

In the transport sectors of all jurisdictions there are no GHG reduction targets or mechanisms. Nor is the possibility of raising transport fuel prices as a means of reducing VKT and incentivising the uptake of more fuel-efficient vehicles mentioned in any policy in any jurisdiction. There is some acknowledgement in all jurisdictions of the links between urban form and per capita VKT and ultimately GHG and brown pollution. A policy direction that runs through most urban planning (land use, transport, and housing) documents is that previous urban development that has privileged motor vehicle use is no longer environmentally, socially or economically sustainable, and an alternative model is required for future development. Specific issues highlighted are excessive GHG pollution, but also traffic congestion and

other negative health consequences, such as the encouragement of sedentary lifestyles, social isolation, and inequities stemming from differential access to, places, services, and employment. For example, the SEQ Plan argues:

SEQ has developed historically in a dispersed, low-density settlement pattern, which has moved outward into the regional landscape. This pattern has become unsustainable. The natural landscape and regional ecosystems are experiencing increasingly adverse effects, and SEQ residents are experiencing increasing traffic congestion and, therefore, longer journeys to and from work… & … Groups with the highest needs are often concentrated in urban fringe locations, rural areas, and some suburbs where public transport and services are unavailable or inadequate (DPI, 2009).

The response to these problems in all jurisdictions is a preference for infill within current urban footprints attached to existing or proposed public transport infrastructure and services, for example:

Higher residential densities and mixed use developments in the walkable catchments of transit facilities have the potential to reduce car dependence; to increase accessibility for those without access to private cars; to reduce congestion on the road network and the demand for new road space; to reduce fuel consumption and air pollution; and to provide quality diverse and affordable forms of housing and development. These benefits combine to produce an attractive and viable alternative to car-based suburban and urban fringe development (WAPC 2010).

As strategy, this involves the targeting of higher density residential infill in city centres, and in inner and middle suburbs within walking distance of transit corridors such as rail lines, busways, and arterial roads with high frequency bus services. In middle and outer suburbs, a transit-oriented development (TOD)approach of targeting residential infill within walking distance of regional and district level activity centres attached to public transport interchanges is common.

The targeting of residential infill around activity centres in middle and outer suburbs is part of a strategy to space and connect activity centres to form an activity centre network across metropolitan areas. The objective is for major district and regional centres to become diverse, mixed use nodes with a greatly expanded commercial, service, social and employment functions. The long term aim is to make suburban regions more commercially and socially self-reliant, and by doing so improve access to services and employment for suburban residents, reducing the need for commuting into employment dense regions such as the CBD and inner suburbs. There is belief in all jurisdictions that these strategies will reduce VKT causing a corresponding reduction in both GHG and brown pollution.

In regard to the pollution effects of cold running and short trips only the NSW Long Term transport Strategy even mentions these as a problem.

Maintaining Sydney's air quality Cold start VOC (volatile organic compound) pollution – the pollution produced immediately after the car starts – contribute 54 percent of total petrol passenger vehicle exhaust VOC pollution and 39 percent of fleet total pollution. In other words, numerous short journeys

*contribute more pollution than the same total number of kilometres travelled as a long journey. This means that reversing the large increase in short car trips that has occurred in recent years – trips that could be taken by walking or cycling – can make a significant contribution to improving air quality (*Transport for NSW 2012)*.*

The transit-oriented development (TOD) approach also advocates improving public transport and cycling connections into suburban activity centres as an alternative to short journeys by car, for example in WA the plan is to:

plan and design activity centres around transit-oriented development principles to promote public transport, walking and cycling as an alternative to private car use (WAPC 2010).

However, a complementary strategy of restricting or applying costs to parking as a means of reducing motor vehicles trips into suburban activity centres is not advocated in any jurisdiction.

In addition, targeting intensive residential infill into inner city suburbs and close to major activity centres, and arterial roads creates a significant issue for health and health equity because these areas are also areas where brown pollution is most concentrated (Oakes et al., 2016, Marshall et al., 2009). Only the Melbourne plan raises the potential of the problem, stating:

As urban renewal progresses, more people could be exposed to air and noise pollution in mixed-use areas, along major roads, at intersections, in popular entertainment areas and near industrial areas (DELWP, 2014).

The means of dealing with this issue and its health and health equity implications is to have a corresponding policy initiative to reduce brown pollution from the motor vehicle fleet (Tayarani et al., 2016). The Melbourne Plan like the NSW *Cleaner Vehicles and Fuels Strategy* advocates for this to be done nationally.

The Council of Australian Governments sets emission standards through national environment protection measures, which are designed to minimise the potential pollution impacts of urban living (such as motor-vehicle pollution). Victoria will work to ensure that these national measures set pollution requirements to manage pollution levels (DELWP, 2014)*.*

The mechanisms for action to improve the pollution standards of new vehicles and fuel is the National Clean Air Agreement tends to downplay the problem of brown pollution stating in its introduction:

Australia's air quality remains very good by world standards. Australian governments have, over a number of years, successfully implemented measures to reduce air pollution which have significantly improved Australia's overall air quality and resulted in positive environmental and health outcomes. But there is more that can be done (DAWE, 2016).

While there is a mention of the potential of 'more to be done' there are no policies designed to improve the pollution standards of new vehicles in this document.

The problem of congestion is espoused as a far greater concern than brown pollution in all jurisdictions. Its economic effects are regularly highlighted with evidence, such as this from SEQ:

Road connections within SEQ are increasingly under pressure, with congestion and delays reducing economic efficiency and costing industry millions per year. The Australian Infrastructure Audit estimates the cost of delays on the Brisbane–Gold Coast–Sunshine Coast transport network caused by congestion in 2011 was around $2 billion. In the absence of any additional capacity, the cost of delays across the region is projected to grow to around $9 billion in 2031 (DILGP 2016).

Investments into public transport and to a lesser extent walking and cycling infrastructure are advanced as means of reducing congestion with the potential for GHG and brown pollution reduction expressed as co-benefits. In land use plans ensuring new residential areas are walkable is a common objective and all jurisdictions have strategies to improve cycling infrastructure. However, the funding commitments to these are comparatively modest. In addition, there are plans to expand light and/or heavy rail infrastructure in larger cities; primarily as a means of reducing congestion but also increasing urban development opportunities and improving the city's global connectedness. For example,

The Melbourne Rail Link will support an expanded central city through provision of new stations at Domain, and Montague (in the Fisherman's Bend Urban Renewal Area). These new stations will create new opportunities for high value businesses and residential development. The Melbourne Rail Link includes the Airport Rail Link, a frequent and reliable rail service running between Melbourne Airport, the CBD and Melbourne's south-east, and providing the benefit of directly linking Melbourne Airport to Sunshine and Southern Cross station. The Airport Rail Link will provide convenient and alternate landside access to one of our most important transport gateways and an important connection for business travellers and tourists looking for a frequent, reliable connection to the central city. With the Cranbourne-Pakenham Rail Corridor Project, the Melbourne Rail Link will increase capacity across the network by 30 per cent (DELWP 2014).

There is in all transport plans a far greater commitment to upgrading and expanding road infrastructure as a means of alleviating 'productivity stifling' congestion than for public or active transport infrastructure, for example:

Significant improvements to and expansion of the road network in the Perth metropolitan area are planned and will be required in the future to meet the transport demands that will be generated by further expansion and development within the metropolitan area. Planned upgrades include six-lane freeways on Roe and Tonkin highways interspersed with four-lane highways and traffic signalised intersections.

There is also likely to be the need to plan for some new road infrastructure to ensure that adequate accessibility is provided and maintained across the metropolitan area. For example, the north-south East

Wanneroo Link will be required to support additional development in the north-west sub-region (WAPC 2010).

The federal government infrastructure plan even sees reducing road traffic congestion as a means of reducing pollution, arguing:

Vehicles use less fuel and produce less pollution on free-flowing road networks than those that are congested (Infrastructure Australia, 2016).

The dubious notion that it is possible to encourage active and public transport and therefore reduce motor vehicle reliance while simultaneously making driving a more attractive option is a common acceptance in all jurisdictions. It is specifically argued in the following extract from the South Australian *Integrated Transport and Land Use Plan*.

The Plan seeks to reduce reliance on car travel across inner and middle Adelaide by supporting development around transport hubs and encouraging the use of public transport and the creation of more jobs closer to where people live, including in the CBD. Investment in infrastructure to support public transport, cycling and walking when coordinated into existing networks and integrated with land use and the design of walkable and cyclist-friendly environments can help reduce car dependency. Improvements to major traffic routes will reduce the need for travel through the inner city, and make it easier to get around Greater Adelaide by car. Solutions will be put in place that help take the cars and trucks that don't need to be in the city out of central Adelaide and off streets that are not major traffic routes, while still protecting important freight corridors and routes (DPTI, 2015).

4.4 The protection of Urban Ecological Services

All urban planning and environment documents in all jurisdictions have objectives and strategies to protect, enhance, and expand green infrastructure (parks, open spaces, riparian corridors, and coastal areas) and their urban ecological services (UES). For example:

Protect, manage and rehabilitate riparian areas to maintain and enhance their water quality, scenic, biodiversity, ecological, recreational and corridor values (DPI, 2009).

There is some recognition of the UES green spaces provide in relation to pollution mitigation in environment sector documents but far less in urban planning documents. The contribution hard infrastructure associated with car dependence such as wide roads, freeways, and surface level carparks makes to the pollution of water and natural environments is a silence in urban planning sector documents. There is some recognition of the UES provided by urban street tree canopies and landscapes in Victoria, NSW, SA, and WA and the negative aspects of their loss due to intensive infill. For example, Plan Melbourne states;

our city's green spaces are under increasing pressure from drought, climate change and the increasing cost of water. Growth and increasing density are reducing the size and number of private gardens and

opportunities for street trees and landscaping in our newer suburbs (DELWP, 2014).

The common response to this problem are strategies to plant more trees in public places: For example:

Encourage local governments to undertake community tree-planting programs by building on the success of the 2 Million Trees Project beyond 2014 (DELWP, 2014).

Urban planning documents also routinely mandate water sensitive urban design (WSUD) principles be incorporated into new residential developments and redevelopments. In addition, an often-mentioned co-justification for favouring urban infill over continued extensive expansion on urban fringes is to protect natural environments and agricultural land. For example, *Principle 14 (b) ii* of South Australia's *Planning, Development, and Infrastructure Act (2016)* states

the encroachment of urban areas on areas of rural, landscape or environmental significance is to be avoided other than in exceptional circumstances (Attorney General's Department, 2016)

In support of this principle the Thirty-Year Plan for Greater (TYPGA) has a policy to:

Ensure new urban fringe growth occurs only within designated urban areas and township boundaries and outside the Environment and Food Production Areas (DPTI 2017).

However, SA, along with NSW, Qld, WA, and Vic temper strict environmental preservation regulations with environmental offset policies. These allow a developer to destroy a natural ecosystem for urban development if they construct or rehabilitate a degraded ecosystem of equal or greater environmental value elsewhere. For example, the Queensland State Planning policy states:

(b) where existing wetland environmental values cannot be enhanced or adverse effects on wetland environmental values cannot be avoided, the development:

i. minimises those adverse effects, or ii. provides an environmental offset for any remaining environmental impacts, where those adverse effects cannot be minimised (DILGP. 2017).

The *NSW Wetlands Policy* similarly states:

Natural wetlands should not be destroyed or degraded. If social or economic imperatives in the public interest result in a wetland being degraded or destroyed, the establishment and protection of a wetland offset that supports similar biodiversity and ecological functions will be needed (DECCW, 2010).

5. Discussion

This research has provided an assessment of the extent to which urban planning, environment, and energy sector policies confront the issue of pollution. The document analysis shows environmental sustainability is a goal in all jurisdictions and is commonly advanced across sectors with a primary focus on reducing GHG pollution. However, despite its significant burden on population health, brown pollution

does not receive a priority focus in any sector in any jurisdiction. Instead, it is understated as a problem and its amelioration is usually viewed as a secondary benefit of policies designed to advance other objectives.

5.1 Pollution reduction in the stationary energy sector

There are objectives and often KPI targets in the energy plans of all state and territory jurisdictions to increase renewable electricity generation. In the years since the release of these energy plans, there has been a strong uptake of renewable energy generation in Australia due to a combination of abundant wind and solar resources, rapidly falling costs of wind and solar generators, the incentives provided by the renewable energy target, and a short-lived carbon price from 2011 to 2014. Therefore, Australia reached its national 2020 RET target, and has seen a fall in GHG emissions from electricity since 2005. However, there have been no similar targets or mechanisms to reduce GHG emissions from transport and they have risen since 2005. If the controversially included reductions from land clearing are removed, Australia's total GHG emissions have increased by approximately 10% since 2005 (DISER, 2019).

In 2020 the RET expired without a replacement, leaving Australia with no enforceable mechanism for reaching the GHG reduction and renewable energy objectives of federal, state and territory jurisdictions. Australia's energy system is market based with large numbers of private operators in generation, transmission, and distribution. Therefore, market incentives are vital to expediate a sustainable energy transition. Pollution pricing has proven to be the quickest and most effective mechanism for reducing GHG and brown pollution and appeared to be effective in Australia for a brief period (Echenique et al., 2012, Neuman, 2005, Handy, 2005, Best et al., 2020)

In addition, the absence of complementary policies to expedite the closure of coal generators in jurisdictions with large coal industries is a major impediment to a nationally coordinated SET. A failure to price pollution or hamper the advantages of established coal generators can also lead to incongruous outcomes such as that experienced in South Australia. In this case, it resulted in renewable wind and solar resources being backed up for many years by old, inefficient, high emission but cheaper brown coal generators, while lower emission natural gas generators sat idle (McGreevy et al., 2020).

The obvious contradiction between policy support for renewables without complementary policies to price pollution and phase out fossil fuel generation federally and in the NT, NSW, Qld, and WA is substantially due to the importance of the fossil fuel industry and its exports from these jurisdictions (Ayling, 2017, Hobbs and Swiatek, 2019, Warren et al. 2016). This economic importance has given the fossil fuel lobby significant political influence in the states where it is mined (NSW, Qld, WA and NT) and over federal governments (Ayling, 2017; Byrnes et al., 2013, Cheung & Davies, 2017, Hobbs and Swiatek, 2019, Warren et al. 2016). This factor is also potentially behind the silences observed in these jurisdictions about the adverse health effects of brown pollution from coal mining, transport and burning.

The slow uneven transition in the electricity sector is a concern in all GHG emitting sectors because an economy wide SET will inevitably require the substitution of fossil fuels with electricity. For example, in the transport sector petrol and diesel cars, buses, planes, and commercial vehicles will need to be replaced with electric alternatives. If a SET does not occur rapidly in the stationary energy sector first, transitioning transport vehicles from petrol to electricity is likely to have a relatively small effect on GHG pollution, and simply shift brown pollution from cities to towns where electricity is generated with adverse effects on the health of residents in these regions. Therefore, the early policy priority given to an energy transition ahead of a transport transition has some justification. However, without incentives to expediate the replacement of coal generation with renewables, renewables are unlikely to replace much current electricity demand, let alone increased demand from sustainability transitions in other sectors such as transport.

5.2 Pollution reduction in the land use and transport sectors

There are numerous objectives and strategies in the urban planning sector that are claimed to reduce both GHG and brown pollution. Paramount amongst these are policies that favour infill development and redevelopment in targeted public transport rich and walkable locations over extensive greenfield development on the urban fringe. Replacing fringe development with infill will on a metropolitan scale reduces pollution over the long term because in all Australian cities both average commuting distances and car use increase the further a residential area is from the CBD and more compact development reduces urban freight VKT (Zhao and Li, 2017).

However, an unintended or possibly ignored consequence of the targeted infill envisaged is that it increases the number of people living in areas of concentrated pollution. This creates the paradox of reducing total GHG and brown pollution by placing increasing numbers of residents in locations where brown pollution is most concentrated (Zhao and Li, 2017, Næss, 2014). In all jurisdictions there is a notable silence on this potential health issue despite it having been discussed in urban planning literature for some time (Zhao and Li, 2017, Tayarani et al., 2016, Schindler and Caruso, 2014, Cervero, 2000, Schweitzer and Zhou, 2010, Marshall et al., 2009, Marshall et al., 2005).

Promoting health and health equity demands that the targeting infill into areas of concentrated pollution such as transport corridors and activity centres be accompanied by policies to reduce brown pollution from Australia's motor vehicle fleet (Tayarani et al., 2016). However, policies aimed at improving the efficiency of motor vehicles purchased in Australia are minimal. Some state and territory governments have instigated, policies to reduce pollution from their car fleets and public transport vehicles, however, legislative power to improve the efficiency of all vehicles and the quality of fuels burnt primarily rests with the federal government, whose standards are extremely weak on both counts by international standards. Furthermore, in the years since the release of the National Clean Air Agreement (DAWE, 2015) sales of diesel powered off road vehicles has increased and the uptake of hybrids and EVs has been slow compared to many other high income countries (Smit, 2019, Schofield et al., 2017).

The reasons behind Australia's reluctance to embrace cleaner vehicles and fuels and silences when it comes to the health effects of the brown pollution from them are not as obvious as its economically based support for coal. Australia has not had a car manufacturing industry since 2017 and it imports most of its liquid fuels (DFAT, 2019). It is most likely that the reasons are political, leading to a reluctance to see fossil fuel pollution in general as a problem, and a reluctance to confront a popular desire for large energy inefficient and polluting motor vehicles and cheap fuel.

The objective in all jurisdictions of decanting jobs to the middle and outer suburbs has potentially many social, economic, and environmental benefits. However, there is also potential for unintended consequences regarding pollution. The objective runs the risk of reducing journey length but not the number of motor vehicle trips and encouraging the replacement of long journeys via public transport with shorter journeys via private motor vehicle. If this was to occur it would result in a continuation and/or possible increases in cold running trips unless strategies are simultaneously introduced to deter suburb to suburb driving such as safe, reliable, and convenient public transport and cycling connections into suburban activity centres and inconvenient and expensive suburban car parking. There are objectives in land use and transport plans to facilitate the former but not the latter.

The primacy of economic benefit has also resulted in the great bulk of transport infrastructure funding being channeled towards relieving peak hour congestion as a means of boosting economic productivity. Although often advocated in tandem with policies to increase the use of active and public transport, the largest investments into congestion alleviation in all jurisdictions are in new and/or upgraded road infrastructure. While this priority is unlikely to have much long-term effect upon congestion, it is highly likely to make motor vehicle use more convenient than public transport outside peak times and make active transport less safe and attractive at all times (Adkins et al., 2012, Newman and Kenworthy, 2015). Furthermore, research shows the most effective means of inducing a journey transfer from cars to active transport and public transport are ensuring the latter two are at least as safe, convenient, reliable, and fast as the former. In this regard congestion is a major inducer of increased public transport and active transport uptake where quality infrastructure is in place (de Dios Ortuzar and Willumsen, 2011, Cervero and Hansen, 2002).

5.3 Pollution reduction, UES enhancement and retention

While all land use plans provide often detailed evidence of the negative social, environmental, and economic effects of greenfield growth on the urban fringe, all jurisdictions still anticipate a share of new residential development continuing to take place there. This will result in more GHG and brown pollution and potentially the loss or degradation of natural environments on or near the urban fringe. This can be directly by their bulldozing, or more commonly by drawing the urban interface and its hard surfaces closer to them, resulting in more polluted runoff inundating them as well as pest intrusions from weeds and carnivorous pets. Due to their urban proximity these ecosystems are the most likely to perform UES, so their loss is likely to have comparatively high social, environmental and economic losses (Brueste et al., 2013).

The policy response in most jurisdictions to this potential loss of ecosystems in and on the fringes of urban areas is environmental offsetting. Environmental offsetting is a highly controversial practice because of the difficulty of finding and measuring temporal biodiversity equivalence (McKenney and Kiesecker, 2010, Bekessy et al., 2010). In addition, an emphasis on offsetting, seen as no net loss or gains in biodiversity, could potentially exchange an ecology providing UES for one more distant from an urban area on private land that does not (Tratalos et al., 2007, Bekessy et al., 2010, Ives et al., 2017).

There is recognition that infill also has the potential to lead to the incremental loss of the urban tree canopy and its UES (Kaspar et al., 2017, Byrne et al., 2010). The strategic response to this problem is to plant more trees in public spaces. However, replacing mature trees with saplings results in a short to medium term loss of canopy and the UES they provide. Therefore, policies to preserve mature vegetation that provide UES on private land undergoing redevelopment are needed.

6. Conclusion

Successful sustainable energy transitions that consider the health effects of both GHG and brown pollution require coordinated economy wide responses across jurisdictions and sectors. Our analysis shows such coordination is currently absent in Australia.

We highlight that in complex socio-technical systems there are seldom perfect solutions and unintended but often foreseeable consequences are inevitable. One we have observed is that prioritizing infill over extensive fringe growth and decanting commercial activity and jobs to the suburbs can have the positives benefits of reducing average VKT and therefore reducing average per capita levels of GHG and brown pollution. It also protects green spaces on the urban fringe from the polluting effects of urban development. However, it also has the foreseeable consequence of placing more residents in area of concentrated brown pollution and causing a loss of private greenspace and the UES they provide in established suburbs.

These consequences do not provide justification for fringe development, however, they do require complimentary suites of responses to reduce brown pollution such as improved motor vehicle efficiency standards, cleaner fuels, the replacement of diesel buses and commercial vehicles with electric alternatives, and policies that encourage suburb to suburb journeys to be shorter and taken by public or active transport. Our analysis has shown a lack of policy commitment to any of these. Indeed, these are contradicted by transport investments geared to reducing traffic congestion, particularly road building. Evidence shows reducing the numbers of cars on the road, VKT and the congestion and pollution caused by these requires investments into public and active transport as convenient and safe alternatives.

The primacy given to stationary power as the focus of an economy wide sustainable energy transition via a now expired RET has some merit, however, the absence of legislated federal targets and mechanisms post 2020 means renewable generation is likely to struggle to meet current electricity demand let alone the increased demand that will be required for a SET in other sectors such as transport but also industry and agriculture. In addition, a price on pollution is required to ensure unintended but foreseeable

consequences are avoided, by providing financial incentives to decommission the highest sources of both GHG and brown pollution (currently brown coal generation) first and to not use them as a back up to renewables in the transition period ahead of lower emission gas and storage. Furthermore, a price on pollution will help prevent an uptake of electric vehicles transferring brown pollution from cities to towns where coal is burned to supply urban electricity demand. Overall Australia could do significantly more to reduce the health harms from urban pollution through more innovation in urban planning, transport, energy, and environmental policies. Doing this will require sufficient political will to challenge fossil fuel invested interests.

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The documents used for data collection are all publicly available.

Code availability

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Authors' contributions

Michael McGreevy: Investigation, Formal analysis, Data Curation, Writing - Original Draft, Writing - Review & Editing.

Patrick Harris: Conceptualisation, methodology, formal analysis, reviewing and editing, supervision of staff, project administration and funding acquisition.

Fran Baum: Conceptualisation, methodology, formal analysis, review and editing, supervision of staff, project administration and funding acquisition.

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8. References

1. ADKINS, A., DILL, J., LUHR, G. & NEAL, M. 2012. Unpacking Walkability: Testing the Influence of Urban Design Features on Perceptions of Walking Environment Attractiveness. *Journal of Urban Design,* 17, 499-510.
2. AER, 2019. State of the Energy Market May 2018, Australian Competition and Consumer Commission. Canberra: Commonwealth of Australia.
3. ASTELL-BURT, T. & FENG, X. 2019. Association of Urban Green Space With Mental Health and General Health Among Adults in Australia. *JAMA Netw Open,* 2**,** e198209.
4. AYLING, J. 2017. A contest for legitimacy: the divestment movement and the fossil fuel industry. *Law & Policy,* 39**,** 349-371.
5. BACCHI, C. 2009. *Analysing policy: What's the problem represented to be?,* Frenchs Forest, NSW, Pearson Education.
6. BARBIER, E. B. & HOCHARD, J. P. 2018. The impacts of climate change on the poor in disadvantaged regions. *Review of Environmental Economics and Policy,* 12**,** 26-47.
7. BEKESSY, S. A., WINTLE, B. A., LINDENMAYER, D. B., MCCARTHY, M. A., COLYVAN, M., BURGMAN, M. A. & POSSINGHAM, H. P. 2010. The biodiversity bank cannot be a lending bank. *Conservation Letters,* 3**,** 151-158.
8. BELLARD, C., BERTELSMEIER, C., LEADLEY, P., THUILLER, W. & COURCHAMP, F. 2012. Impacts of climate change on the future of biodiversity. *Ecology letters,* 15**,** 365-377.
9. BEST, R., BURKE, P. J. & JOTZO, F. 2020. Carbon Pricing Efficacy: Cross-Country Evidence. *Environmental and Resource Economics*.
10. BOLLETER, J. & RAMALHO, C. E. 2014. The potential of ecologically enhanced urban parks to encourage and catalyze densification in greyfield suburbs. *Journal of Landscape Architecture,* 9**,** 54-65.
11. BRIDGES, A., FELDER, F. A., MCKELVEY, K. & NIYOGI, I. 2015. Uncertainty in energy planning: Estimating the health impacts of air pollution from fossil fuel electricity generation. *Energy Research & Social Science,* 6**,** 74-77.
12. BYRNE, J., SIPE, N. & SEARLE, G. 2010. Green around the gills? The challenge of density for urban greenspace planning in SEQ. *Australian Planner,* 47**,** 162-177.
13. BYRNES, L., BROWN, C., FOSTER, J. & WAGNER, L. D. 2013. Australian renewable energy policy: Barriers and challenges. *Renewable Energy,* 60**,** 711-721.
14. CALTHORPE, P. 1993. *The next American metropolis: Ecology, community, and the American dream,* New York, Princeton architectural press.

15. CALTHORPE, P. & FULTON, W. 2001. *The regional city*, Island Press.
16. CARLEY, S. 2009. State renewable energy electricity policies: An empirical evaluation of effectiveness. *Energy Policy,* 37**,** 3071-3081.
17. CERVERO, R. 2000. Transport and land use: Key issues in metropolitan planning and smart growth.
18. CERVERO, R. 2002. Induced travel demand: Research design, empirical evidence, and normative policies. *Journal of Planning Literature,* 17**,** 3-20.
19. CERVERO, R. & HANSEN, M. 2002. Induced travel demand and induced road investment: a simultaneous equation analysis. *Journal of Transport Economics and Policy (JTEP),* 36**,** 469-490.
20. CHEN, H., et al. 2017. Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. *The Lancet,* 389**,** 718-726.
21. CHEUNG, G. & DAVIES, P. J. 2017. In the transformation of energy systems: what is holding Australia back? *Energy Policy,* 109**,** 96-108.
22. CLUNE, S., MORRISSEY, J. & MOORE, T. 2012. Size matters: House size and thermal efficiency as policy strategies to reduce net emissions of new developments. *Energy Policy,* 48**,** 657-667.
23. CONNOR, L., ALBRECHT, G., HIGGINBOTHAM, N., FREEMAN, S. & SMITH, W. 2004. Environmental change and human health in Upper Hunter communities of New South Wales, Australia. *EcoHealth,* 1**,** SU47-SU58.
24. CORBIN, J. & STRAUSS, A. 2008. *Basics of qualitative research,* California, Sage Publications.
25. COSTELLO, A., et al. 2009. Managing the health effects of climate change: Lancet and University College London Institute for Global Health Commission. *The Lancet,* 373**,** 1693-1733.
26. DE DIOS ORTUZAR, J. & WILLUMSEN, L. G. 2011. *Modelling transport*, John Wiley & Sons.
27. DIPROSE, K., LIU, C., VALENTINE, G., VANDERBECK, R. M. & MCQUAID, K. 2019. Caring for the future: Climate change and intergenerational responsibility in China and the UK. *Geoforum,* 105**,** 158-167.
28. ECHENIQUE, M. H., HARGREAVES, A. J., MITCHELL, G. & NAMDEO, A. 2012. Growing cities sustainably: does urban form really matter? *Journal of the American Planning Association,* 78**,** 121-137.
29. EWING, R., HAMIDI, S. & NASAR, J. L. 2015. Compactness versus Sprawl. *Journal of Planning Literature,* 30**,** 413-432.
30. EWING, R. & HANDY, S. 2009. Measuring the Unmeasurable: Urban Design Qualities Related to Walkability. *Journal of Urban Design,* 14**,** 65-84.
31. FRANK, L. D., ANDRESEN, M. A. & SCHMID, T. L. 2004. Obesity relationships with community design, physical activity, and time spent in cars. *Am J Prev Med,* 27**,** 87-96.
32. FRANK, L. D. & ENGELKE, P. 2005. Multiple impacts of the built environment on public health: walkable places and the exposure to air pollution. *International Regional Science Review,* 28**,** 193-216.
33. GEELS, F. W. 2011. The multi-level perspective on sustainability transitions: Responses to seven criticisms. *Environmental Innovation and Societal Transitions,* 1**,** 24-40.

34. GÓMEZ-BAGGETHUN, E. & BARTON, D. N. 2013. Classifying and valuing ecosystem services for urban planning. *Ecological Economics,* 86**,** 235-245.
35. GREENWALD, M. J. 2003. The road less traveled: New urbanist inducements to travel mode substitution for nonwork trips. *Journal of Planning Education and Research,* 23**,** 39-57.
36. HANDY, S. 2005. Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us? *International Regional Science Review,* 28**,** 146-167.
37. HANDY, S. L. & CLIFTON, K. J. 2001. Local shopping as a strategy for reducing automobile travel. *Transportation,* 28**,** 317-346.
38. HANKEY, S., LINDSEY, G. & MARSHALL, J. D. 2017. Population-level exposure to particulate air pollution during active travel: planning for low-exposure, health-promoting cities. *Environmental health perspectives,* 125**,** 527-534.
39. HARMAN, B. & CHOY, D. L. 2011. Perspectives on tradable development rights for ecosystem service protection: lessons from an Australian peri-urban region. *Journal of Environmental Planning and Management,* 54**,** 617-635.
40. HESS, D. J. 2014. Sustainability transitions: A political coalition perspective. *Research Policy,* 43**,** 278-283.
41. HIGGINBOTHAM, N., FREEMAN, S., CONNOR, L. & ALBRECHT, G. 2010. Environmental injustice and air pollution in coal affected communities, Hunter Valley, Australia. *Health & Place,* 16**,** 259-266.
42. HILLSDON, M., PANTER, J., FOSTER, C. & JONES, A. 2006. The relationship between access and quality of urban green space with population physical activity. *Public Health,* 120**,** 1127-32.
43. HOOPER, P., KNUIMAN, M., FOSTER, S. & GILES-CORTI, B. 2015. The building blocks of a 'Liveable Neighbourhood': Identifying the key performance indicators for walking of an operational planning policy in Perth, Western Australia. *Health Place,* 36**,** 173-83.
44. HUA, Y., OLIPHANT, M. & HU, E. J. 2016. Development of renewable energy in Australia and China: A comparison of policies and status. *Renewable Energy,* 85**,** 1044-1051.
45. IVES, C. D., OKE, C., HEHIR, A., GORDON, A., WANG, Y. & BEKESSY, S. A. 2017. Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. *Landscape and Urban Planning,* 161**,** 32-43.
46. KARNER, A. A., EISINGER, D. S. & NIEMEIER, D. A. 2010. Near-roadway air quality: synthesizing the findings from real-world data. *Environmental science & technology,* 44**,** 5334-5344.
47. KASPAR, J., KENDAL, D., SORE, R. & LIVESLEY, S. 2017. Random point sampling to detect gain and loss in tree canopy cover in response to urban densification. *Urban Forestry & Urban Greening,* 24**,** 26-34.
48. KIM, K. H., KABIR, E. & KABIR, S. 2015. A review on the human health impact of airborne particulate matter. *Environ Int,* 74**,** 136-43.
49. KÖHLER, J., et al. 2019. An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions,* 31**,** 1-32.

50. LARONDELLE, N. & HAASE, D. 2013. Urban ecosystem services assessment along a rural–urban gradient: A cross-analysis of European cities. *Ecological Indicators,* 29**,** 179-190.
51. LI, H. X., EDWARDS, D. J., HOSSEINI, M. R. & COSTIN, G. P. 2020. A review on renewable energy transition in Australia: An updated depiction. *Journal of cleaner production,* 242**,** 118475.
52. LIAMPUTTONG, P. & EZZY, D. 2006. *Qualitative Research Methods,* Melbourne, Australia, Oxford University Press.
53. LOORBACH, D. 2010. Transition management for sustainable development: a prescriptive, complexity-based governance framework. *Governance,* 23**,** 161-183.
54. COSTANTINI, M. et al. 2010. Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure, and Health Effects. *In:* POLLUTION, H. P. O. T. H. E. O. T.-R. A. (ed.) PRESS VERSION ed. Boston, Massachusetts: Health Effects Institute.
55. MARKANDYA, A., et al. ARMSTRONG, B. G., HALES, S., CHIABAI, A., CRIQUI, P., MIMA, S., TONNE, C. & WILKINSON, P. 2009. Public health benefits of strategies to reduce greenhouse-gas emissions: low-carbon electricity generation. *The Lancet,* 374**,** 2006-2015.
56. MARKARD, J., RAVEN, R. & TRUFFER, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy,* 41**,** 955-967.
57. MARSHALL, J. D., BRAUER, M. & FRANK, L. D. 2009. Healthy neighborhoods: walkability and air pollution. *Environmental health perspectives,* 117**,** 1752-1759.
58. MARSHALL, J. D., MCKONE, T. E., DEAKIN, E. & NAZAROFF, W. W. 2005. Inhalation of motor vehicle emissions: effects of urban population and land area. *Atmospheric Environment,* 39**,** 283-295.
59. MCGREEVY, M., MACDOUGALL, C., FISHER, M., HENLEY, M. AND BAUM, F., Expediting a renewable energy transition in a privatised market via public policy: The case of south Australia 2004-18. *Energy Policy*, *148*, p.111940.
60. MCINTOSH, J., TRUBKA, R., KENWORTHY, J. & NEWMAN, P. 2014. The role of urban form and transit in city car dependence: Analysis of 26 global cities from 1960 to 2000. *Transportation Research Part D: Transport and Environment,* 33**,** 95-110.
61. MCKENNEY, B. A. & KIESECKER, J. M. 2010. Policy development for biodiversity offsets: a review of offset frameworks. *Environmental management,* 45**,** 165-176.
62. MOORE, T., BERRY, S. & AMBROSE, M. 2019. Aiming for mediocrity: The case of australian housing thermal performance. *Energy policy,* 132**,** 602-610.
63. NÆSS, P. 2014. Urban form, sustainability and health: the case of greater Oslo. *European Planning Studies,* 22**,** 1524-1543.
64. NEUMAN, M. 2005. The compact city fallacy. *Journal of planning education and research,* 25**,** 11-26.
65. NEWMAN, P. & KENWORTHY, J. 2006. Urban design to reduce automobile dependence. Opolis 2 (1), 35-52.
66. NEWMAN, P. & KENWORTHY, J. 2015. Urban Transportation Patterns and Trends in Global Cities. *The End of Automobile Dependence: How Cities Are Moving Beyond Car-Based Planning.* Washington,

DC: Island Press/Center for Resource Economics.

67. NEWMAN, P. G. & KENWORTHY, J. R. 1989. *Cities and automobile dependence: An international sourcebook*.
68. NEWTON, P. & GLACKIN, S. 2014. Understanding Infill: Towards New Policy and Practice for Urban Regeneration in the Established Suburbs of Australia's Cities. *Urban Policy and Research,* 32**,** 121-143.
69. NEWTON, P. & GLACKIN, S. 2018. 12 Greyfield regeneration. *Urban Regeneration in Australia: Policies, Processes and Projects of Contemporary Urban Change*.
70. NEWTON, P. W. 2010. Beyond greenfield and brownfield: The challenge of regenerating Australia's greyfield suburbs. *Built Environment,* 36**,** 81-104.
71. OAKES, M. M., BURKE, J. M., NORRIS, G. A., KOVALCIK, K. D., PANCRAS, J. P. & LANDIS, M. S. 2016. Near-road enhancement and solubility of fine and coarse particulate matter trace elements near a major interstate in Detroit, Michigan. *Atmospheric Environment,* 145**,** 213-224.
72. POPE III, C. A., EZZATI, M. & DOCKERY, D. W. 2009. Fine-particulate air pollution and life expectancy in the United States. *New England Journal of Medicine,* 360**,** 376-386.
73. ROBINSON, D. L. 2011. Australian wood heaters currently increase global warming and health costs. *Atmospheric Pollution Research,* 2**,** 267-274.
74. ROGGE, K. S., KERN, F. & HOWLETT, M. 2017. Conceptual and empirical advances in analysing policy mixes for energy transitions. *Energy research & social science,* 33**,** 1-10.
75. DONALDSON, S. & GODDEN, D. 1995. Particulate air pollution and acute health effects. *Lancet,* 345**,** 176-78.
76. SCHINDLER, M. & CARUSO, G. 2014. Urban compactness and the trade-off between air pollution emission and exposure: Lessons from a spatially explicit theoretical model. *Computers, Environment and Urban Systems,* 45**,** 13-23.
77. SCHOFIELD, R., WALTER, C., SILVER, J., BREAR, M., RAYNER, P. & BUSH, M. 2017. Submission to the Department of Environment and Energy in response to their “Better fuel for cleaner air” discussion paper.
78. SCHWEITZER, L. & ZHOU, J. 2010. Neighborhood air quality, respiratory health, and vulnerable populations in compact and sprawled regions. *Journal of the American Planning Association,* 76**,** 363-371.
79. SHOUP, D. 2017. *The high cost of free parking: Updated edition*, Routledge.
80. SKILLINGTON, T. 2019. *Climate change and intergenerational justice*, Routledge.
81. SMIT, R. 2019. Real-world CO2 emissions performance of the Australian new passenger car fleet 2008-2018: impacts of trends in vehicle/engine design.
82. STEVENSON, M., et al. 2016. Land use, transport, and population health: estimating the health benefits of compact cities. *The Lancet,* 388**,** 2925-2935.

83. STONE JR, B., MEDNICK, A. C., HOLLOWAY, T. & SPAK, S. N. 2007. Is compact growth good for air quality? *Journal of the American Planning Association,* 73**,** 404-418.
84. TAYARANI, M., POORFAKHRAEI, A., NADAFIANSHAHAMABADI, R. & ROWANGOULD, G. M. 2016. Evaluating unintended outcomes of regional smart-growth strategies: Environmental justice and public health concerns. *Transportation Research Part D: Transport and Environment,* 49**,** 280-290.
85. TRATALOS, J., FULLER, R. A., WARREN, P. H., DAVIES, R. G. & GASTON, K. J. 2007. Urban form, biodiversity potential and ecosystem services. *Landscape and urban planning,* 83**,** 308-317.
86. TRAVAGLIO, M., et al.., 2020. Links between air pollution and COVID-19 in England. *Environmental Pollution*, *268*, p.115859.
87. WARREN, B., CHRISTOFF, P. & GREEN, D. 2016. Australia's sustainable energy transition: The disjointed politics of decarbonisation. *Environmental Innovation and Societal Transitions,* 21**,** 1-12.
88. WOOD, L., HOOPER, P., FOSTER, S. & BULL, F. 2017. Public green spaces and positive mental health - investigating the relationship between access, quantity and types of parks and mental wellbeing. *Health Place,* 48**,** 63-71.
89. WU, X., NETHERY, R.C., SABATH, B.M., BRAUN, D. AND DOMINICI, F., 2020. Exposure to air pollution and COVID-19 mortality in the United States. *MedRxiv*.
90. WU, X., LU, Y., ZHOU, S., CHEN, L. & XU, B. 2016. Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment international,* 86**,** 14-23.
91. ZHANG, K. & BATTERMAN, S. 2013. Air pollution and health risks due to vehicle traffic. *Sci Total Environ,* 450-451**,** 307-16.
92. ZHAO, P. & LI, P. 2017. Rethinking the relationship between urban development, local health and global sustainability. *Current Opinion in Environmental Sustainability,* 25**,** 14-19.