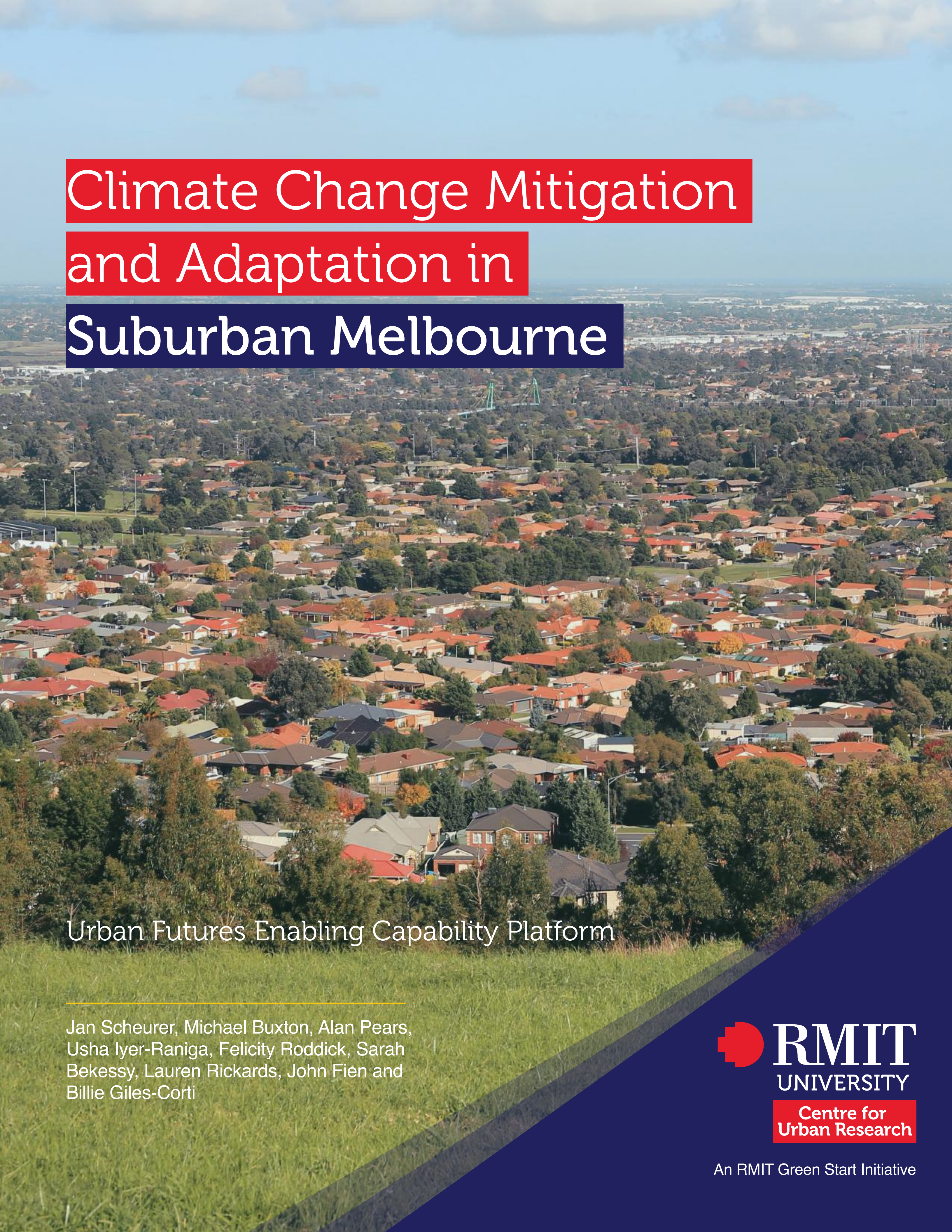

Climate Change Mitigation and Adaptation in Suburban Melbourne

Urban Futures Enabling Capability Platform

Jan Scheurer, Michael Buxton, Alan Pears, Usha Iyer-Raniga, Felicity Roddick, Sarah Bekessy, Lauren Rickards, John Fien and Billie Giles-Corti

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Acknowledgement of Country

We at the Centre for Urban Research and Sustainability & Urban Planning acknowledge the people of the Woi wurrung and Boon wurrung language groups of the eastern Kulin Nation on whose unceded lands we conduct our research, teaching and service. We respectfully acknowledge Ancestors and Elders past, present and emerging who have always been caring for Country. We pay our respects to Country, the lifeworld that sustains us all.

Our research, education and service are already in a relationship with Country and the people of Country, here and in all the places we undertake our business. As mostly non-Indigenous people, we acknowledge our obligation in this relationship: to uphold the ngarn-ga [understanding] of Bundjil and practice respect for community and culture. Though there is much we still need to learn, especially about ourselves, we affirm our dhumbali [commitment] to that work. We hold as central to our business, dhumbali to a shared future with Indigenous peoples everywhere and especially Kulin Country and peoples.

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Authors

Dr Jan Scheurer
Centre for Urban Research
RMIT University, Melbourne

Professor Michael Buxton
Centre for Urban Research
RMIT University, Melbourne

Alan Pears AM
Centre for Urban Research
RMIT University, Melbourne

Professor Usha Iyer-Raniga
Construction Management
RMIT University, Melbourne

Professor Felicity Roddick
Engineering
RMIT University, Melbourne

Professor Sarah Bekessy
Centre for Urban Research
RMIT University, Melbourne

Assoc Prof Lauren Rickards
Centre for Urban Research
RMIT University, Melbourne

Professor John Fien
Landscape Architecture
RMIT University, Melbourne

Professor Billie Giles-Corti
Centre for Urban Research
RMIT University, Melbourne

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Introduction and Overview

In 2019, the Victorian Government and CSIRO estimated that, based on current evidence and an ongoing high emissions scenario, by the 2030s there is very high confidence that in Greater Melbourne daily maximum temperatures will increase by 0.8 to 1.6°C (since the 1990s), and the risk of heat extremes will grow. There is medium to high confidence that rainfall will continue to decline in winter and spring, and low to medium confidence of declines in autumn. Adding to increased fire risk are projected increases in thunderstorms, and a high likelihood of more intense extreme rainfall events. Sea levels are projected to rise by approximately 14 cm, increasing the risk of further coastal inundation and erosion.

All of these impacts are projected to intensify greatly by 2070 and will increasingly co-occur and compound (DELWP/CSIRO, 2019).

This brief report outlines state-of-the-art climate change mitigation and adaptation measures for urban development and redevelopment in both new and established suburbs in Melbourne in support of the United Nations' Sustainable Development Goals (SDG). It discusses practice solutions for the reduction of greenhouse gas emissions, the management of known climate change risks, the development of adaptive capacity by increasing flexibility and resilience, the systemic interactions between different disciplinary themes and principles, and potential governance arrangements that seek to integrate climate mitigation and adaptation measures into planning practice.

Climate change risks and impacts in Melbourne's suburbs

Melbourne's suburbs are both contributors to and at risk from climate change hazards. Compared with other cities globally, Melbourne's suburbs are prolific users of energy and other resources, including land: their urban density is generally low, leading to high land consumption and a prevalence of motorised transport to get around; they are dominated by detached single-family housing as one of the least energy and resource-efficient building types; typical subdivision layouts and house designs lack energy-saving characteristics such as solar orientation, local destinations and permeability of neighbourhoods for walking and cycling.

Simultaneously, Melbourne's suburbs are affected by the impacts of increasingly frequent extreme weather events such as heatwaves and droughts, and high precipitation leading to flooding. Depending on their location, they are also exposed to growing risks from bushfires and/or coastal flooding due to sea level rise.

Climate change adaptation: Reducing hazards, exposure and vulnerability

Recent years have seen the emergence of numerous innovations to address climate change-related challenges in Melbourne's suburbs, both spontaneous through markets and communities and planned through public policy. This includes:

1. Previously highly centralised energy and water supply/disposal systems have begun converting to more distributed networks with a greater role for renewable energy sources, the integration of natural hydrological and biological cycles and associated household or community stewardship (DELWP, 2017b). A proliferation of small-scale energy generation (rooftop photovoltaics) and efficiency improvements, water management (local storm water collection and use, wastewater recycling) and biodiversity-supportive design in public and private open spaces has reduced resource inputs and improved resilience against increasing fluctuations of their centralised supply.
2. Upgraded policies and guidelines for precinct planning aim to better integrate residential and non-residential uses and higher densities in order to make most daily needs accessible within a 20-minute journey by walking (DELWP, 2019).
3. New forms of shared micro-mobility (such as fleet bikes or electric

scooters) as well as the rollout of ride sharing services and, in the foreseeable future, autonomous vehicles may further reduce the momentum for the high levels of household car ownership currently typical for Melbourne's suburbs. To avoid further urban sprawl and associated traffic congestion, the introduction of autonomous vehicles will need to be carefully managed.

Simultaneously, numerous barriers exist for the rapid and comprehensive uptake of these reforms and innovations. This report analyses the state of knowledge and practice in climate change adaptation and mitigation policies, measures and implications in Melbourne's suburbs from the seven disciplinary perspectives of urban form, transport, urban biodiversity and biophilic design, bushfire risk, energy management, water management, construction material and waste management.

Each section draws on the broad expertise of researchers within the RMIT Urban Futures Enabling Capability Platform affiliates and positions it within the context of local and international literature and best practice in the wider subject area. By identifying the key barriers and opportunities in the contemporary policy process, we conclude each section with a set of challenges and recommendations for the next wave of reform to make Melbourne's suburbs more resilient to the mounting impacts of global heating and its implications at the local scale.

Broader planning perspectives and governance implications

The magnitude of the climate change adaptation and mitigation challenges in Melbourne's suburbs raises the question of suitable implementation mechanisms and governance arrangements to address them. Hurlimann and March (2012) argue that planning systems have traditionally had a passive focus on the control or prevention of particular activities, with agency for change vested in individual planning proponents rather than regulatory bodies. To do justice to the climate change challenge with its inherently long-term horizon of gradually building impacts, a more proactive approach by planning agencies is required, with a shift in perspective from a dominant focus on new development to a long-range regulatory vision for change of both new and existing built areas.

This aligns to Llausàs et al's (2016) critique of land use planning regimes in Victoria being excessively concerned with the impact of individual development applications in lieu of a focus on their cumulative effects. This is particularly problematic in peri-urban areas where over time, the piecemeal mediation of competing agricultural, conservation and rural residential interests tends to create a largely unregulated patchwork of land uses characterised by high resource use, increased vulnerability to bushfires and other environmental consequences. To address these shortfalls, an additional layer of risk management for climate change-related impacts is required as part of the regulatory system, using the precautionary principle in anticipating and managing change and uncertainty (Buxton et al, 2011). Within urban areas, the 1990s 'Urban Villages' and 'Greenhouse neighbourhood' studies explored many aspects of low carbon urban development and provided insights into the kinds of development directions and policies needed for low carbon development.

Such a step-change in planning system capacity is no less significant in established suburban areas. Newton et al (2017a) speak of the transformative capacity of stakeholder groups in the context of renewal of greyfield suburban areas towards higher land use yield and a transition towards regenerative practices in energy, water, waste, mobility and green space use. They see a greater need for horizontal (interdepartmental) and vertical integration (between tiers of government) of the planning system at state level, and for up-skilling and better resourcing local government to handle more complex planning decisions in the light of broader sustainability and climate change adaptation challenges.

Meanwhile, community expectations towards housing provision are changing from a near-universal preference for the detached suburban home a generation ago to a more diversified picture embracing higher-density and urban amenity-rich dwelling types with a greater requirement for public and shared open space, a shift that the property development industry has not been sufficiently equipped to respond to at scale (Dalton and Nelson, 2015).

Thus in order to facilitate the delivery of effective outcomes that meet climate change mitigation and adaptation challenges in suburban Melbourne, the Victorian planning system needs to build the capacity at both state and local level to take a more proactive role in formulating strategic, long-term objectives for a low-carbon, risk-mitigated urban environment; it needs to establish suitable regulatory mechanisms over and beyond traditional planning control and mediation processes to implement these; and it needs to provide leadership for public and private stakeholders to build the skills, community support and industry capacity for transformative change. It must also be better integrated with building policy and regulation, and health and amenity performance. In the concluding section of this brief, we will revisit and discuss these aspects of governance reform in the context of the findings from each of the seven disciplinary areas.

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Plan for higher density development and integrated services

The urban form and structure of suburban areas in Melbourne is linked to climate change mitigation and adaptation goals in a variety of ways. Most critically, Melbourne's suburbs are generally characterised by low densities in all land use categories – residential, commercial, industrial and infrastructural. This circumstance leads to a high rate of land consumption with concomitant impacts on policy areas such as biodiversity protection and water management, as discussed in the relevant sections of this report.

Insufficient land use mix combined with low density residential housing increases the need for travel due to long distances between points of human activity. This settlement pattern generates spatially diffuse movement needs that are predominantly met by the most carbon-intensive modes of surface transport (private cars and trucks), with poor access to public transport and marginalising walking and cycling. This effect is exacerbated by a legacy of segregation of different land uses, especially the placement of retail facilities in large, free-standing shopping centres and bulky goods stores configured almost exclusively around car access (Goodman and Coote, 2007), that is only gradually being overcome by a paradigm of greater integration in newer precincts.

As Australian cities have shifted from the industrial to the knowledge economy as the basis of their wealth, the importance of clustering activities in such integrated districts in order to facilitate the associated human exchange has grown. There is thus greater pressure on the planning process to facilitate more spaces where different modes of transport and a variety of land uses can coexist to mutual advantage (Van den Boomen and Verhoeven, 2012; Florida, 2017).

Walkability in suburban development

In 2017, Melbourne's metropolitan strategy (Plan Melbourne) raised the concept of the 20-minute city as a sub-regional design principle, stipulating that the majority of daily needs should be serviceable within a 20-minute walking, cycling and/or public transport trip from a person's residence across Melbourne's suburbs (DELWP, 2017a; Newton et al, 2017b). Stanley et al (2015) identify the urban form elements that support this vision by stimulating walking, cycling and the use of public transport as local destinations, mixed land uses, dwelling density and street connectivity. Walkable catchments are defined as distances up to 800 metres, and a density of 25 dwellings per hectare recommended as a threshold for number and diversity of destinations within that range (DELWP, 2019). Having access to destinations is a key driver of using active modes, and without sufficient density, there are insufficient residents to support local shops, services and public transport. In areas with densities exceeding 25 dwellings per hectare, people are more likely to walk, cycle and use public transport, and less likely to drive (Boulange et al, 2017).

There is also evidence that for walking and cycling, the presence of infrastructure such as foot or cycling paths has a positive influence on mode share. Perceived and actual safety is a further important influence for these transport modes: this is connected to exposure to traffic, traffic calming and the design of road intersections. This is particularly important for children, with parents fearful of allowing their children to walk to school or in neighbourhoods with higher levels of traffic, or when children are required to cross busy roads (Giles-Corti et al, 2011). Green and open space and an 'aesthetic' environment also have a positive influence on walking and cycling, although the influence is not as strong as for other urban form elements (Kroen, 2019). However, there is evidence that smaller public open spaces are less likely to encourage recreational walking than larger, attractive ones (Koohsari et al, 2018); it is therefore suggested that providing fewer higher quality larger parks is preferable to many small parks with no amenities (Sugiyama et al, 2015).

The integration and transfer between public transport and walking and cycling is important in the sense that the proximity of public transport stops can increase the likelihood of walking for transport (Rachele et al, 2018). There is evidence that those with proximate access to public transport near home and near their work were 16 times more likely to use public transport (Badland et al, 2014).

Victoria's Precinct Structure Planning (PSP) Guidelines, where implemented to standard, ensure that most residents will have access to open space close to their home. Other local destinations and mixed land uses are stipulated to be mainly concentrated in town centres, but also in community hubs or employment areas. These areas are also planned to be integrated with public transport and the cycling and walking network. The PSP guidelines set a benchmark that new town centres be established for catchments of 2,500 to 3,500 dwellings, and that an overall 80-90% of households should be located 'within 1 km of a town centre including a supermarket' (Element 3: Town Centre Design, Standard 3). These standards are currently not being achieved in Melbourne (Arundel et al, 2018), with only half of PSP areas having reached this number of dwellings also having opened town centres (personal communication, VPA 2020). Moreover, in any event a 1-km catchment standard may not be sufficient to break the dominance of car access to these centres as the propensity of shoppers to walk to supermarkets has been shown to recede at shorter distances, such as 800 or even 500 metres (Boulange et al, 2017; Gunn et al, 2017). It also exceeds the 800m walkable catchment for local amenities (outlined in the context of density (as discussed below) in the 20-minute neighbourhoods report (Hooper et al, 2015).

A further drawback is that in the absence of special incentives for early implementation, new suburbs are often developed in sequences not conducive to a high uptake of walking trips as residents move in (Newton et al, 2017b). Typically, town centres and their variety of local destinations tend to be built as one of the last elements of new suburbs due to viability considerations (Kroen, 2019). While a PSP can call for town facilities to be provided and can set land aside for this purpose, it cannot compel the providing entity to establish these facilities.

Land use density

The current PSP guidelines specify an average residential density goal in new growth area development of 15 net dwellings per hectare. This density level reflects an increase compared with common practice at the beginning of the century (Buxton and Scheurer, 2007), but continues to be at the low end of what has been found to support widespread walking and cycling (Boulange et al, 2017). It is likely significantly too low to support a viable, car-competitive public transport service, which has been suggested to require a residential density of 25-30 (Stanley and Hansen, 2020) or even 35 net dwellings per hectare (Giles-Corti et al, 2014b).

Plan Melbourne 2017-2050 flags goals of higher densities in suburban development (beyond the 20 net dwellings per hectare mark), and a differentiation to increase these goals further close to activity centres and high-quality public transport (DELWP, 2017a). The 20-minute neighbourhood concept goes further to recommend 25 dwellings per hectare as the target required to achieve this policy aspiration (DELWP, 2019). Research has found that more people would prefer to live in semi-detached housing and apartments in the middle and outer areas of Melbourne and Sydney than is offered (Kelly et al, 2011). A governance gap between the responsibilities of the VPA in preparing PSP guidelines and the PSPs themselves, and those of local councils in the development approval process frequently leads to suboptimal implementation of density targets. Furthermore, mobilising the behavioural implications of the juncture of higher density and greater public transport usage requires the delivery of residential development and public transport infrastructure and services to be more or less synchronised, calling for coordination efforts among an even larger number of agencies (Kroen, 2019).

Street connectivity is considered in PSP documentation through a standard for highly permeable street blocks and a road grid of 800m (connector streets) and 1.6 km (arterial roads). However, no clear definition is given of "high permeability". The literature suggests, as rules of thumb, that block sizes in walkable areas should be relatively uniform and generally not exceed one hectare in size, though meaningful measures capture a more complex picture (Pafka and Dovey, 2017). Empirical work suggests that people are more likely to walk in neighbourhoods with a minimum of 150 intersections within an 800-metre (200-hectare) radius (Badland et al, 2019).

Tax reform to facilitate urban intensification and functional integration

Barriers to more walkable, dense and functionally diverse suburban neighbourhoods extend as far as the tax system. Wood et al (2012) evaluate the comparative merits of stamp duties on property transactions and the alternative of a broad-based land tax. They cite widespread criticism of stamp duties as inefficient fiscal instruments that penalise an activity with no undesirable effect on community wellbeing, act regressively in disproportionately impacting on lower income-groups and negatively affecting housing affordability by adding to property prices. By inflating the cost of property transactions, stamp duties can disincentivise land use intensification in public transport-accessible neighbourhoods as well as individual households moving in response to changing needs, which may lead to overcrowding in the case of growing families as well as under-occupation in the case of family disintegration. As more and more cities devise place-making strategies around transport hubs in a bid to integrate land use and transport, and to prioritise pedestrians and reduce the impact of automobiles in activity centres (Curtis et al, 2009), taxation regimes that slow this process can be considered counter-productive to urban policy goals.

In contrast, a broad-based land tax applied to all urban land uses is likely to be indirectly priced into property transactions and thus exercise downward pressure on land values, improving affordability for both residential and non-residential uses. Simultaneously, by being applied to the site value rather than the capital-improved value of a property, a broad-based land tax incentivises land owners to put vacant or underutilised urban sites to better use and, as long as agricultural land in the outskirts of the city is not subject to the tax (thus reducing the financial incentive to urbanise it), can act as a mechanism to encourage intensification within the existing urban footprint (Wood et al, 2012).

Summary and recommendations

There is a relative consensus among policy makers and empirical evidence that significant energy efficiency could be achieved through denser urban development. Higher urban density and mixed use development can reduce the urban environmental footprint and provide residents with closer access to services and amenities, enhancing liveability and reducing the need to travel. Providing higher density energy-efficient housing in established areas close to jobs and services would also reduce the need for new housing on the urban fringe. However, numerous barriers to achieving best outcomes in these respects remain in place.

- Strategic density targets in new suburbs are too low, exacerbated by too-generous space allocations for roads and parking. Even current modest density targets are not always being achieved.
- Policies to encourage development sequencing that would deliver a full array of local retail, services and public transport access within walking distance in sync with residential completions are absent or insufficiently effective.
- The taxation regime on property has room for improvement when it comes to facilitating urban intensification and housing affordability.

Key Recommendations

- Develop a long-term strategic plan for climate change mitigation and adaptation in Melbourne's suburbs that encompasses new and existing built areas.
- Increase density and diversity in targeted areas of Melbourne's established suburbs, focused around the public transport network and activity centres.
- Raise the minimum dwelling density target for suburban development in PSP areas to at least 25 dwellings per hectare in residential areas, with higher density development around activity centres.
- Facilitate development sequencing in growth areas that provides for the early delivery of local amenities to support walkable neighbourhoods and access to public transport, active transport and co-located services.
- Consider the replacement of property stamp duty with a broad-based land tax to facilitate urban intensification and support housing affordability.

Enhance access to sustainable modes of transport

In residential growth areas at the urban fringe, transport-related climate change mitigation and adaptation challenges primarily relate to the high levels of car use typically observed there, and the corresponding weakness of public transport, walking and cycling as viable mobility options for residents, visitors and employees. These patterns are associated with high transport energy use and hence, high CO2 emissions (Chapman, 2007). They are also associated with specific vulnerabilities concerning the future availability and affordability of transport fuels and of car-based mobility in general, exposing households to uncertainty whether reliable travel options to meet their daily needs will persist in line with current expectations (Dodson and Sipe, 2008). Reducing car dependence in Melbourne's suburbs thus forms a critical element in both climate change mitigation and adaptation strategies.

Public transport networks

The availability and quality of a public transport network is clearly a determinant of public transport use; as are the comparative financial and other incentives given to different transport modes, and the influence of personal and social preferences. Means of influencing travel behaviour thus include supporting policies, marketing campaigns, market-based instruments and metropolitan-wide and network planning.

Melbourne's PSP Guidelines set a spatial coverage goal for public transport in residential growth areas, specifying that 95% of dwellings be located not more than 400 metres street walking distance from the nearest existing or proposed bus stop. However, in 2017 only 14% of suburbs in Melbourne met the target that 95% of dwellings should have access to a public transport stop within 400 metres. Across the metropolitan area, only 69% of residences were within the specified proximity to public transport. When a minimum service frequency of 30 minutes was applied, this number reduced further to only 36% of residences (Arundel et al, 2018).

Moreover, this coverage goal is not matched by a patronage goal (Walker, 2008; 2012). In Victoria, no standards exist concerning level of service (frequency and span), range and location of destinations served and directness of the routes (impacting on travel time): Stanley et al's (2015) recommendation that local bus routes supporting the concept of the 20-minute neighbourhood should have a minimum all-day service frequency of 30 minutes (though 20 minutes is preferable) is not codified in the PSP Guidelines or elsewhere in Victoria. Nor is there routine consideration in the PSP process of how the bus routes connect into a local network, and how the performance of this network can be optimised. In short, the public transport standards followed in growth areas are largely about endowment, not performance: they acknowledge the 'social safety net' role of public transport but do not necessarily aim for the maximisation of public transport mode share (Dodson, 2007; Mulley et al, 2017; Scheurer et al, 2017).

Alongside low-density suburban development, this shortfall facilitates (and perhaps necessitates) excessive car dependence in Melbourne's suburbs. Nevertheless, Mees (2010) has argued that low densities in suburban areas cannot serve as a valid constraint on policy choices to provide high quality public transport where there is adequate political will. Nevertheless, outer urban growth areas, are at a specific geographical disadvantage here. Due to their peripheral location, their public transport services can only marginally capitalise on the presence of movement flow through the area, to and from other origins and destinations. In the terminology of network analysis, they are characterised by inherently lower betweenness centrality compared with urban areas closer to the central city (Neal, 2013; Curtis and Scheurer, 2016).

Public transport planning in suburbs that prioritises maximising patronage as much as (or more highly than) providing spatial coverage would seek to fill the performance gap between the first tier of radial rail lines and the third tier of local bus lines by establishing a second tier of frequent, direct services providing intra- and inter-suburban links between town centres, neighbourhood centres, train stations and employment/education hubs. Such services tend to require good traffic priority and where feasible, exclusive rights-of-way to be effective. They can be operated by regular buses or, as the concentration of land uses in their catchments increases, a medium-capacity mode such as Light Rail, Trackless Trams or Bus Rapid Transit (Nielsen et al, 2005; Dodson et al, 2011; Orth et al, 2015).

A sequence of metropolitan strategies and transport plans has stipulated outer suburban extensions or upgrades of rail lines, including electrification and additional tracks to Melton, Wyndham Vale and Wallan, and new branch lines or extensions to Epping North/Wollert, Doncaster, Rowville and Cranbourne East/Clyde. There is also an ambitious plan for an orbital Suburban Rail Link to connect middle suburban activity hubs and thus relieve the radial rail system from pressure at the centre while providing new car-competitive options for public transport movement between suburbs.

New heavy rail lines, however, require high capital investment, particularly where they require tunnelling as is likely the case for a large proportion of the Suburban Rail Link. Funding for such projects has generally been raised from state budgets with project-based and often ad-hoc assistance from federal government through the Infrastructure Australia agency. It is unlikely that the pace of funding through these arrangements will be sufficient to fully support the necessary transition of Melbourne's metropolitan transport system away from car dependence and towards greater public transport orientation. An emerging model to overcome this constraint is to afford a greater role to land developers and private capital in the process of rail planning and implementation, and thus mobilise the substantial increase in land values experienced as a result of new rail station infrastructure as an additional private funding source. This is known as the Entrepreneur Rail Model (Newman et al, 2016; Newton et al, 2017).

Shared, micro and autonomous mobility

Car dependence in Melbourne's suburbs may also be addressed by the ongoing emergence of new forms of shared and micro-mobility, and the possible shift to widespread use of autonomous vehicles. Shared electric vehicles, bicycles or scooters can help expand the catchment of destinations or rail stations by adding 'last-mile' transport options with lower spatial and carbon impact than the private car (Lindsay, 2016). Their ubiquitous availability may reduce the rationale for the typically very high levels of household car ownership in suburban areas and allow for reduced provision of parking space at both residences and destinations (Fagnant and Kockelman, 2016; Milakis et al, 2017).

However, the encouragement of micro-mobility requires infrastructure. To foster active transport modes, there is a need for safe cycling infrastructure within 5 km of public transport hubs and train stations and activity centres, even in outer suburban areas (Giles-Corti et al, 2014a).

There is also a policy and regulatory gap between the objectives of public authorities and those of the private industry players developing and marketing the new transport technologies and services – a gap that may require capacity building efforts within public authorities to bridge (Stone et al, 2018). Shared and autonomous mobility technologies are not specifically designed by market players to address sustainability shortfalls or address climate change adaptation and mitigation challenges, though they may achieve some benefits in these respects. Rather, they are developed and brought to market as commercial opportunities, even with the intent to disrupt current patterns of urban mobility, invariably inferring mismatches between public and private interests concerning their roll-out and usage (Legacy et al, 2018). As an example, the commercial operators of fleet-based shared vehicles and micro-mobility options often prefer to deploy their products in inner urban areas, where they find greater a spatial concentration of potential users even though such areas already offer a greater diversity of travel options (Currie, 2018). To provide a similar density of service in more sparsely populated and/or more peripherally located suburban neighbourhoods, fleet operators may require additional financial or regulatory incentives. Conversely, declining ownership cost and improving range and performance of micro-mobility devices in combination with their portability on public transport may reduce reliance on shared vehicle schemes and assist in building further synergies between public and individual transport modes for integrated trip-making.

On a broader level, the emergence of autonomous vehicles may encourage further suburban sprawl if not well managed through policy, as well as increases in total traffic and thus in upward pressure on carbon emissions. This is due to the greater availability of private vehicle travel to groups currently not in a position to drive because of age or disability, incentives to undertake longer journeys as the productive or recreational value of in-vehicle time increases for occupants relieved of driving tasks, and the emergence of a significant amount of empty-running autonomous vehicles as they travel between passenger trips (Milakis et al, 2017).

Summary and recommendations

Both climate adaptation and mitigation in suburban areas require a reduction of car dependence among residents, visitors and employees. This can be achieved by various measures. The walkability of urban environments in both new and existing areas can be increased through greater density and diversity, better connected street networks, more dedicated walking, cycling and micro-mobility infrastructure, and traffic calming measures as planning and design objectives. Growth of public transport use and enabling public transport to substitute for a sizeable share of car journeys requires a proactive approach to network planning on behalf of public agencies, and the identification and development of a 'second tier' of patronage-driven, frequent and prioritised medium-capacity routes. New modes of shared, autonomous and micro-mobility can contribute to providing 'last-mile' transport options integrating with line-haul public transport, walking and cycling and thus further reduce the need for car use and ownership; however, it is likely that the wide deployment of these modes in suburban areas requires investment in safe cycling infrastructure within 5 km of all train stations and activity centres, and financial and regulatory support to operators or lower purchase costs for individual ownership.

Key Recommendations

- Victorian government commitment to improved minimum standards for frequency and operating hours of public transport services, with PSP guidelines providing clear criteria on network design including route destinations and route directness.
- Create walkable mixed-use neighbourhoods with destinations needed for daily living that include safe cycling and micro-mobility infrastructure within 5km of train stations, activity centres and public transport hubs
- Investigate the potential for second tier, medium capacity public transport services that provide faster access between higher-density neighbourhood centres, train stations, employment and education hubs.
- Investigate opportunities for smart fleet-based shared vehicle and micro-mobility options, including consideration of financial or regulatory incentives for fleet operators.

Preserve and Enhance Biodiversity

Climate change-related effects such as heatwaves, droughts, bushfire and high-intensity precipitation events place stress on animal and plant communities in urban areas and their catchments. This potentially degrades remaining habitats, reducing the diversity and distribution of species and consequently, impacting negatively on broader ecosystem services such as microclimatic cooling, air and soil humidity, absorption of pollutants and carbon sequestration (Norton et al, 2015; Duncan et al, 2019). These processes may also lead to the deterioration of human health by exacerbating adverse climate effects associated with extreme weather, and by eroding the mental health benefits of human interaction with natural environments (Newman et al, 2017; Garrard et al, 2018). They also increase the stresses on urban infrastructure and increase the need for safe refuges for people and animals, and protection of vegetation from extremes. Achieving biodiversity benefits and providing green infrastructure in urban areas thus constitutes a potent climate change mitigation strategy.

In addition, the pressures on non-urban land for purposes of agriculture, forestry, waste management, energy production and further urbanisation can be attributed to the resource consumption demands of cities and urban processes (Güneralp et al 2013, Llausàs et al 2016, Roös 2019). Losses in natural vegetation associated with these effects at and far beyond the city limit disrupt and impoverish the broader carbon cycle and reduce the rate of terrestrial carbon sequestration needed to tackle climate change (Shukla et al. 2019). These losses can also substantially exacerbate climate change risks by degrading water catchments and altering groundwater recharge, thereby threatening water quantity and quality and amplifying flood risk (Han et al. 2017, Löwe et al. 2017, Shi et al 2019).

Nature conservation in urbanising areas has traditionally been pursued as a defensive endeavour, with biodiversity considered a constraint on development and strategic planning seeking to spare sanctuaries of high ecological value from the spread of human settlements regarded as inherently hostile to the biosphere (Bekessy et al, 2012; Ives et al, 2016). On the other hand, successful examples exist in outer urban areas of integrating multi-purpose regional parks and conservation reserves with expanding urbanisation, such as the Plenty Valley Gorge in Melbourne's northeast where land zoning was used as a conservation tool since the 1980s to limit developable land in the corridor to 35% and protect stands of 500-year-old River Red Gums (Buxton and Butt, 2020). Melbourne Water's biodiverse water management solutions on waterways also illustrate how integrated development and conservation outcomes can be achieved.

Biodiversity-sensitive design

An emerging paradigm seeks to integrate the needs of human and non-human spaces by removing the dichotomy between city and nature and creating a symbiotic and synergistic relationship between them (Newman et al, 2017; Tjallingii, 1995). From this framework of thought, Parris et al (2018) formulate seven principles for retaining and enhancing biodiversity in the city.

Conceiving cities as environments of benevolence towards non-human life, in an analogy to the principle of universal design in planning for a diversity of humans needs and abilities. Examples include the mitigation of invasive species through indigenous landscaping and pet containment programs, the mitigation of storm water runoff through water-sensitive design, and the mitigation of noise and light pollution. The principle also relates to human and non-human interaction through public engagement with and local stewardship of biodiversity assets (Garrard et al, 2018). Examples include Friends groups on the Merri Creek, coastal vegetation and other threatened areas, who enhance council rate revenue as well as protecting biodiversity and creating valued recreational resources.

Protection of existing and potential areas of high biodiversity in the city and its catchments. Bekessy et al (2012) developed a decision-making tool for the urbanisation process that departs from the traditional practice of earmarking selected areas as enclaves for conservation while neglecting biodiversity requirements on development land. Instead, areas of lowest ecological value are identified to be prioritised for urban development, leaving existing biodiversity hotspots and their linkages in place. The common policy lever of requiring offsets for biodiversity assets lost to urban development by revegetation programs elsewhere is criticised as insufficient to stem the degradation of species and their habitat, as it fails to take into account the fixed spatial and temporal character of these assets as well as the cumulative effects of multiple land use changes (see also Garrard et al, 2018).

Connectivity between areas of habitat in the urban landscape, to enable the mobility of animals and the dispersal of plant species, as well as pathways for people. This is generally enabled through a network of habitat connectivity corridors incorporating both public and private land, though it is noted that these may also facilitate the spread of invasive species unless well managed (Garrard et al, 2018). In established urbanised areas with an absence of such corridors, similar functions can sometimes be retrofitted through green infrastructures such as landscaping in public streets, exhumation of storm water drains and green roofs or facades on buildings (Norton et al, 2015).

Managing energy, water and nutrient cycles at the local scale to minimise the disruption to these functions prompted by the urbanisation process and increasing climate extremes. In many cities, a large proportion of impervious surfaces serviced by reticulated drainage systems reduce the amount of storm water that is retained locally through evapotranspiration, soil infiltration or capture for on-site irrigation compared to the pre-urbanisation environment. Similar losses occur in the local soil nutrient cycle through wind erosion, runoff and removal of plant litter (Parris et al, 2018). A shift from centralised, linear to decentralised, circular resource management is designed to mitigate these imbalances.

Fostering biological interactions between species in urban environments. This concerns natural competitive and symbiotic relationships such as between predator and prey, or between pollinators and plant species. Urbanisation-related disruption to these processes degrades biodiversity as well as human food supplies (Parris et al, 2018) and amenity, and can be counteracted by resources targeting specific species, pollinator habitat and safe management of flood or fire events (Garrard et al, 2018).

Construction of new habitat as part of the urbanisation process, acknowledging that the high structural diversity of human-made environments also has the potential to translate into ecosystem complexity. This includes green infrastructure elements as listed above, and is related to the concept of biophilic urbanism (see below).

Making room for novelty, ie. the evolution of new ecological communities specifically adapted to a variety of urban conditions which allow for an increasingly rich mosaic of habitats, analogous to the richness experienced in human-made environments where elements of different historic eras and planning paradigms mingle (Parris et al, 2018).

Biophilic urbanism

The concept of biophilic urbanism expands on the environmental management features of biodiversity-sensitive urban design (detailed above) by further acknowledging the innate connection of humans and nature as an impetus to integrate green infrastructure and nature-based design principles into built environments and urbanites' daily lives (Newman et al, 2017). Climate mitigation and adaptation elements of biophilic urbanism include a greater appeal of denser urban fabric through more prolific green elements (potentially leading to reductions in transport energy use and the rate of development on greenfield sites), additional carbon sequestration through an increase in vegetation, and a reduction of the urban heat island effect and associated excess energy use (see also Duncan et al, 2019). Evidence further points to benefits for human health and wellbeing, recovery rates in hospitals and reductions in crime and violence associate with greater human exposure to nature. Economic benefits include greater worker productivity, attraction of skilled employees due to greater appeal of the working and general urban environment, increased amenity of commercial areas and higher property values where green infrastructure elements are in place (Newman et al, 2017).

Summary and recommendations

Biodiversity in Melbourne's suburban and peri-urban areas is under the combined stress of urban development and climate change-related impacts such as increasing droughts, heatwaves, bushfires and flooding. Urban vegetation supports urban resilience through carbon absorption, cooling urban temperatures and flood mitigation, as well as sustaining urban wildlife and peri-urban food production. The “re-naturing” of urban areas also enhances the urban environment and contributes to residents’ health and well-being (Newman et al., 2017).

Biodiversity can be enhanced through biodiversity sensitive urban design (BSUD) (Garrard et al, 2017). Rather than offsetting biodiversity to sites away from cities, BSUD seeks to enhance the onsite persistence of species and ecosystems through careful planning and design. This includes setting clear biodiversity objectives, providing habitat and resources for target species/ecosystems, mitigating potential risks and planning for connectivity between areas of habitat. In this way, the urban fabric can be designed to be less hostile to biodiversity and can deliver ‘everyday nature’ experiences needed to enhance residents’ health and wellbeing. An important first step is locating new urban development on land of low biodiversity value (Parris et al, 2018). BSUD could be explicitly incorporated into the Melbourne Strategic Assessment to enhance biodiversity outcomes near where people live, work and play and mitigate negative impacts of urban development. Strategic assessments incorporating BSUD should be similarly applied to logical inclusion areas and fast-growing peri-urban areas.

New urban development should be concentrated on land of low biodiversity value. Where there is urban renewal within established suburbs, aesthetic, health and well-being benefits can be advanced through biophilic urbanism principles, promoting design that enhances residents’ connection to nature.

Key Recommendations

- Explicitly include biodiversity-sensitive urban design in planning design guidelines and in Strategic Assessments.
- Replace biodiversity off-setting in urban developments with a focus towards development within land of low biodiversity value and enhancing onsite biodiversity.
- Promote biodiversity-sensitive urban design and biophilic urbanism principles in urban renewal projects to enhance both biodiversity and liveability, and minimise tree canopy and green space loss.

Bushfire risk mitigation

The bushfire catastrophe in south-eastern Australia during the summer of 2019-20 has sharpened the focus on natural disaster brought on by extreme weather events both as an expression of ongoing global climate change and as a significant risk to human and non-human life and wellbeing. Across the OECD, Victoria is one of the most susceptible regions to disastrous fire events (Buxton et al, 2011; Gill et al, 2013). This century, bushfires have extended well beyond the urban edge into the Sydney metropolitan area while the 2009 Victorian bushfires affected the urban edge of the South Eastern Melbourne growth corridor and destroyed houses to within a few kilometres of the Bendigo CBD. The 2003 Canberra fire, destroying over 480 houses and killing four people, is the most notable example of a bushfire causing devastation in Australian suburban environments.

Given the increasing frequency and severity of bushfires and other extreme weather events, mitigation challenges primarily focus on the reduction of CO2 and other greenhouse gas emissions across all sectors of society in line with international goals to limit global heating. Adaptation challenges concern strategies to reduce harm to human settlements, and to contain and reverse the deterioration of the natural environment from the impacts of bushfires and other extreme weather events.

Bushfire impacts

Bushfires have direct impacts on global atmospheric conditions and air quality through smoke pollution, including, in adverse weather conditions, at some distance from the areas affected by burning. The impacts on biodiversity are massive, including spikes in wild animal mortality both through direct fire impact and through starvation and predation in the aftermath. As fire frequency and severity increase, maladapting plant and animal species can be affected by local or temporary extinction. Storms in the immediate aftermath of bushfires can lead to increased soil erosion and run off, affecting river systems. Aquatic habitats can also be subjected to changes in water flow and temperature, and the chemical composition of water and sediments (Gill et al, 2013).

Human society is affected by extreme fire events through the loss of lives, in the majority of cases from heat exposure or through car accidents while fleeing the flames (Koksal et al, 2019), as well as the impact of emotional and economic stress (Gibbs et al, 2013), homelessness and the cost of support and recovery efforts. Property damage includes the loss of homes, in the majority of cases through ignition by ember attack (March and Rijal, 2015; Koksal et al, 2019), and the loss of agricultural assets including livestock, fencing and buildings. The 2019-20 fires showed that the housing at greatest risk is scattered dwellings in relatively small lots across landscapes and residential and rural-residential lots on the edges of cities and towns. However, suburban areas are also affected: as urban growth pushes further into high-risk peri-urban areas, they become increasingly susceptible to bushfire, including grass fires. Up to 700,000 Victorians can be considered as living in areas of high bushfire risk, and the legacy of inappropriate development in these areas suffers from a lack of effective policies and funding targeting retrofits of existing dwellings towards greater bushfire safety (Buxton and Butt, 2020).

Fire suppression efforts bear their own risk to life and wellbeing for the personnel involved, and both direct financial costs and opportunity costs when volunteer firefighters are unable to engage with their regular employment or business activities. In the recent fire season, lives were said to have been lost in unprecedented fire conditions, including vehicles being turned over in fire tornados. Bushfire damage leads to financial burdens for the insurance industry and disadvantage to individuals as insurance premiums rise, or particular properties or risks become uninsurable (Gill et al, 2013). The time taken to rebuild and unexpectedly high costs and restrictions due to tighter building fire resistance regulations can add to trauma and undermine community viability.

Notably, currently Australian authorities and policy frameworks generally place a greater value on the protection of human life and property than on other assets such as biodiversity when it comes to addressing bushfire risks (Neale et al, 2016).

Responses to bushfires

While bushfires are inherently less predictable than other types of natural disasters, sophisticated tools exist to model fire behaviour to meaningfully inform emergency management as well as design and planning responses (Buxton et al, 2011; March and Rijal, 2015). More recently, regulation has concentrated on increasing the potential for dwellings to survive bushfire through higher construction standards and maintaining 'defendable space' around dwellings. However, little attention has been given to preventing further inappropriate subdivision, construction of dwellings and even multi-unit developments on vacant lots in highly fire-prone areas on the urban fringe of cities (Buxton and Butt, 2020).

The vulnerability of homes to bushfires can be reduced through measures such as the use of non-flammable construction materials, ember-repellent design, provision of defendable space around the structure, vegetation management, static water supply and purpose-built fire shelters (Gill et al, 2013). Regulation introduced after the 2009 Black Saturday bushfires now mandates the precautionary application of most of these standards for new construction through a Bushfire Attack Level (BAL) categorisation to inform the application of Australian Building Standards for bushfire-prone areas (AS3959), and by streamlining the previous planning tool of a council-based Wildfire Management Overlay (WMO; Hughes and Mercer, 2009) into a state-wide Bushfire Management Overlay (BMO; Groenhart et al, 2012; Gonzalez-Mathiesen et al, 2019). However, the degree to which these reforms reflect further climate change-induced deterioration of bushfire risk levels in the future has been questioned (Climate Council, 2019). The reforms also stopped short of introducing a buyback scheme for existing residential properties in areas particularly at risk (McLennan and Handmer, 2012). Thus the effectiveness of property-level risk mitigation depends to a significant degree on the engagement of residents, in particular their level of bushfire preparedness and their willingness to accept and cooperate with additional regulation and land management programmes in bushfire-prone areas (Hughes and Mercer, 2009; McLennan and Handmer, 2012) that many residents choose for their scenic values and some only inhabit seasonally (Neale et al, 2016). Individual bushfire preparedness can suffer from low risk perception and competing demands on residents' lives (Koksal et al, 2019) while local government preparedness can also be impacted by competing priorities for public agencies (Hughes and Mercer, 2009; Gonzalez-Mathiesen et al, 2019).

Improving future resilience as part of bushfire recovery incurs the management of bushfire risks as a whole-of-government approach across a range of public agencies – emergency management, land use planning, education, public health, community development – and to also involve non-government groups (McLennan and Handmer, 2012; Davis and Davidson, 2018). Since bushfire characteristics are highly site-specific, according to topography, vegetation, weather patterns and built structures, it is critical to formulate site-specific solutions to risk reduction, and to up-skill relevant practitioners accordingly (March and Rijal, 2015). Victoria's Bushfire Integrated Planning and Building Framework allows for a local overlay to complement the BMO and take such site-specific conditions into account (Groenhart et al, 2012). However, the relatively recent regulatory measures for housing in the BMO usually do not apply to new outer suburban development, despite the increasing risk (Buxton and Butt, 2020).

Summary and Recommendations

As urban growth extends into peri-urban areas, residents and their homes are increasingly susceptible to bushfire risk, including from grass fires. Catastrophic bushfire events such as the 2009 Black Saturday fires and the 2019-2020 fire season have demonstrated that as global heating continues, the increasing frequency and severity of bushfires impacting human settlements call for a new layer of risk management especially in peri-urban areas where a spatial patchwork of natural environments and rural residential development has emerged (Buxton et al, 2011). Fire suppression efforts have been overwhelmed while the limitations of fuel reduction programs, defence/evacuation protocols and ad-hoc, contestable land use decisions in bushfire risk areas have become apparent (ibid).

The increasing frequency and severity of bushfires call for a new layer of risk management. A more systematic planning regime is needed that takes into account the cumulative effects of individual land use decisions in bushfire risk areas, with authority to make broader planning decisions on the basis of the precautionary principle. A whole-of-government approach is required that spans emergency management, land use planning, education, public health and community development.

Greater attention is required on the impact of bushfires on the urban and suburban envelope of metropolitan Melbourne, including the direct bushfire risks at the suburban fringe as well as the effects of particulate pollution associated with bushfire smoke on public health, biodiversity, agriculture and the water supply.

Victoria's Bushfire Integrated Planning and Building Framework allows for a local overlay to complement the state-wide Bushfire Management Overlay, taking site-specific conditions into account (Groenhart et al., 2012). However, there has been little recognition of the potential for bushfire incursion into new outer urban suburbs, and the risks of subdivision and development in highly fire-prone areas on the urban fringe (Buxton & Butt 2020).

Key Recommendations

- Include outer-urban development within the Integrated Planning and Building Framework for Bushfire in Victoria, taking into consideration the cumulative effects of individual land use decisions on regional and sub-regional risk profiles.
- Consider incentives for the retrofit of existing housing and infrastructure in high bushfire risk areas to reduce vulnerability.

Increase energy efficiency and distributed supply

Stationary energy use in suburban areas is directly linked to climate change adaptation and mitigation challenges through the methods of energy generation and distribution, and through the amount, sources and timing of energy consumed in households and businesses. These challenges are being addressed through programs aiming at a reduction of the share of carbon-emitting fossil fuels in the energy supply mix and, to a lesser extent, at greater energy efficiency and smarter management of buildings and equipment. Both processes have important implications on how energy is used and produced in Melbourne's suburbs, and how the regulatory environment, technological and business opportunities, and the lifestyle habits and aspirations of residents intersect.

Electricity supply and distribution

As we move towards a zero carbon, cleaner economy, renewable electricity will play a broader role, replacing end-use combustion of other fuels and reducing urban and indoor air pollution. Electricity supply in Australian cities has traditionally been dominated by centralised generation in large-scale power plants driven by fossil fuels (coal or gas), and in suitable areas, hydroelectric dams. More recently, renewable energy sources, especially wind and solar, have joined the mix. For decades, overall electricity consumption increased roughly in line with economic growth; however, since the late 2000s a decoupling of this relationship has been observed, with the use of grid-supplied electricity declining or stagnant (Sandiford et al, 2015). This trend is largely attributed to the impact of energy efficiency measures in buildings and equipment (see below), consumer responses to relative increases in retail electricity prices, the proliferation of small-scale rooftop solar photovoltaic systems and a net reduction in the scale and number of energy-intensive industrial facilities across the country as restructuring of the economy towards services and high value manufacturing has occurred (ibid).

The speed and scale of these changes was not anticipated by the energy industry or its regulators (Sandiford et al, 2015; Newman et al, 2017). It has led to instances of overinvestment in electricity infrastructure while also opening opportunities for the earlier-than-intended retirement of ageing coal-fired power stations and creating challenges in management of electricity systems. The uptake of rooftop photovoltaic installations in particular has been swift and mostly market-led as the cost of such systems fell into the affordability range of many households and businesses during the past ten years (Newman et al, 2017); a similar price effect is now under way for small-scale battery storage (Harrington and Hoy, 2019). Rooftop PV installations are expected to triple over the period 2015-2025 to reach a generation capacity equivalent to around 20% of current large-scale power generation in the National Electricity Market across Australia's Eastern states (Sandiford et al, 2015).

In combination, the widespread provision of households, apartment buildings or businesses with their own power generation and storage equipment is converting a previously centralised, unidirectional energy supply grid into a complex distributed two-way system. Distributed power generation will reduce the dependence of consumers on grid-supplied electricity overall, while enhancing supply security and resilience. It can thus be understood as a 'disruptive technology' (ibid), potentially calling into question the economics of conventional electricity supply grids (Pears, 2007). It is unlikely, however, that these grids will become obsolete in urban areas, as they retain a useful role in balancing supply and demand peaks and thus maintaining the resilience of the electricity system. This function is being further optimised by the continuing rollout of digital network management technologies such as smart meters and digital analytics (Bulkeley et al, 2014; Newman et al, 2017; Tirado Herrero et al, 2018).

Future trends in electricity consumption in Australian cities are further influenced by the extent and speed at which processes and services currently predominantly fuelled by fossil energy sources such as oil (road transport) and gas (space heating, hot water generation) are converted to electric operation (Sandiford et al, 2015). There is also potential for increased large-scale electricity demand from a growing number of seawater desalination and wastewater recycling facilities as Australian cities are affected by more frequent or intense drought conditions and associated shortages of traditional drinking water supplies (Pears, 2007). It is not anticipated, however, that these additional areas of electricity consumption will dramatically reverse recent downward trends in overall grid-supplied electricity use (AEMO, 2019).

Energy efficiency and Smart Homes

Energy intensity in suburban development is fostered by the dominant building type of single-family detached houses with only patchy attention to optimal thermal performance, solar orientation or design features to facilitate passive solar energy use. Transport energy use is associated with a high dependence on private cars for personal mobility and considered further in the transport section of this report.

Energy efficiency measures in buildings and for electrical appliances have been regulated in Victoria and other jurisdictions since the 1990s, most prominently through the Equipment Energy Efficiency (E3) program (Sandiford et al, 2015) and the National Construction Code. These regulations have led to better building energy standards in new construction as well as upgrades of some existing housing and commercial building stock towards greater thermal efficiency (ibid), beginning to address a situation where Australian buildings were characterised by comparatively poor energy performance in international terms (Pears, 2007). In a combination of new regulated standards and consumer responses to above-inflation increases in electricity retail prices since 2008, significant energy efficiency gains have also been made through the replacement of outdated electrical equipment such as fridges and water heaters (Sandiford et al, 2015). However, part of these achievements is negated by an ongoing trend towards larger dwellings and the increasing penetration of the housing stock by additional electricity-consuming devices such as air conditioning, a process that is likely to continue as Melbourne and other Australian cities are expected to experience more frequent and intense heatwaves in the future (Pears, 2007; Strengers, 2011). Harrington and Hoy (2019) point to the patchy policy environment across Australia concerning energy efficiency and note that few major reviews of building performance standards have occurred during the 2010s.

Furthermore, building energy policies have focused more on winter performance than summer. Recent regulatory changes require compliance with separate summer and winter performance requirements to limit summer overheating and health impacts (ABCB, 2019).

Further opportunities for residential energy efficiency derive from new technological opportunities to introduce cost-reflective electricity pricing (ie. incentivising shifts of power consumption from peak to off-peak times through variable charges), to make detailed electricity use patterns transparent to households through smart meters and monitoring (thus encouraging more conscious operation and replacement choices of equipment), and/or to automate these processes through the introduction of Smart Home software where much of the operation of home technology is shifted to the background of daily life (Tirado Herrero et al, 2018; Pears and Moore, 2019). Strengers (2011) outlines how these innovations disrupt the traditional separation between producers and consumers of energy services by prompting both to enter a proactive co-management relationship of daily practices, in which behavioural and institutional change towards greater resource efficiency may be more effectively achieved than through the traditional, passive tools of regulation and price signals alone. It is noted, however, that Smart Home technology can also have counter-productive effects in terms of energy efficiency where it allows for and fosters more energy-intensive lifestyle expectations such as remote-controlled pre-heating or pre-cooling of homes for comfort, or remote lighting for security (Tirado Herrero et al, 2018). Smart Home technologies may also exacerbate socio-economic inequality where disadvantaged households are less likely to have the flexibility to adapt their daily routines in order to shift power use away from peak times, or to have the funds to pay for the required installations, smartphones and continuous internet access (Bulkeley et al, 2014; Tirado Herrero et al, 2018).

Summary and recommendations

While suburban energy consumption has improved significantly in recent years through energy efficiency measures in buildings and equipment, the single-family detached houses that predominate in residential suburbs remain energy intensive, partly because of increased average house size. High-rise residential apartment buildings also under-perform in energy efficiency (Pitt & Sherry et al, 2016). In housing design, limited attention has been given to thermal performance, solar orientation, passive solar energy or improved summer performance. Energy efficiency opportunities include the introduction of cost-reflective electricity pricing, use of smart meters and monitoring that make electricity use patterns transparent to households, and Smart Home software that automates operation of home technology (Tirado Herrero et al, 2018). Policies and incentives should also seek to provide vulnerable households and tenants access to energy cost-saving technologies in healthy, safe, resilient buildings.

The transition away from centralised, fossil fuel-driven energy supplies towards a greater role of smart energy efficiency and distributed, renewable electricity generation offers opportunities for drastic reductions in the carbon intensity of stationary energy use in suburban areas, as well as for greater engagement of users in shaping practices of both energy generation and usage (Strengers, 2011) and reductions in urban and indoor air pollution.

It is critical that regulators support this transition by setting ambitious energy efficiency and renewable energy targets and by fostering investment in electricity grid infrastructure that, where applicable, prioritises the needs of the emerging distributed supply system and smart, efficient energy use over those of the old centralised supply system (Newman et al, 2017). This may include decentralised energy generation and storage equipment at the neighbourhood scale. It is also imperative to drive multi-disciplinary research and analysis to inform and evaluate these interventions, so that we can learn from experience and drive ongoing innovation. Some of these elements already exist, but there is a greater need for governments, industry, researchers and consumers to work together to deliver improved outcomes (Pears and Moore, 2019).

Key Recommendations

- Introduce more ambitious energy efficiency and renewable energy standards for Victoria that ensure new buildings, particularly high-density housing, achieve high standards of comfort, safety, equity, resilience and energy affordability.
- Ensure housing design guidelines and standards address thermal performance, solar orientation, passive solar energy and improved summer performance.
- Promote industry use of digital analytics, performance monitoring and lifecycle analysis to better integrate into design and report on building energy and sustainability performance, including over a building's lifetime.
- Promote and encourage through financial incentives or regulation improvements to energy and sustainability performance of existing residential and commercial buildings, including for vulnerable households and residential tenancies.
- Modify energy market rules, regulations and policies to support adoption of smart, efficient, distributed energy solutions.

Enhanced water-sensitive urban design

Climate change has a range of impacts on natural hydrological cycles, the supply of water to human settlements and the management of storm water and wastewater. Increased periods of drought in tandem with greater intensity and variability of precipitation lead to more frequent occurrences of both water shortages and flooding events. Longer and more severe heatwaves impact on both demand and supply of water resources, while sea level rise puts low-lying urban land, productive agriculture and water infrastructure at risk in coastal areas. In conjunction with a continued rapid rate of settlement growth, each of these effects challenges conventional approaches to water management in suburban and peri-urban areas and calls for paradigmatic change.

Limitations to centralised water systems

During the 19th century, fast-growing Western cities were typically provided with centralised water supply and sewage disposal facilities for public health and efficiency reasons (Newman and Kenworthy, 1999; Malekpour et al, 2015; Sharma et al, 2016; Hurlimann and Wilson, 2018). Drinking water subsequently came to be sourced from local aquifers and/or surface water reservoirs, while sewage is discharged into rivers and oceans, usually following a treatment process in a centralised facility. Stormwater, too, is generally subject to collection and rapid conveyance into receiving water bodies in a quest to minimise flooding events in urban areas (Fletcher et al, 2015; Moglia and Cook, 2019); in older areas this sometimes occurs in pipes or canals mixed with sewage.

The expansion of the technocratic, centralised approach to water management over rapidly growing urban areas has strained the efficiency of the infrastructure and led to the overexploitation of aquifers and reservoirs in some urbanised regions, an effect that is exacerbated by climate-related influences such as fire and drought, and land use practices such as logging within water catchments. The quality of the resource is threatened by runoff and accumulated contaminants, particularly from pesticides and chemical fertilisers used in agriculture and private gardens, by airborne smoke, dust and ash pollution from bushfires, and extreme weather events, as well as by saltwater intrusion from sea level rises. The content of nutrients in both stormwater runoff and wastewater discharged into natural watercourses is a major source of pollution in rivers and oceans, an effect that is exacerbated during flooding events. As water resources dwindle and become less reliable, there is also an increased risk of uneven competition between users, industries and jurisdictions posing additional distributional challenges to policy makers.

Improving water security

In these circumstances, Moglia and Cook (2019) suggest that the improvement of water security in cities as a strategic response to the impacts of climate change requires a threefold response.

The augmentation of existing water supply sources can ameliorate or delay supply shortages; however, it comes with a range of caveats. These include threats to areas of considerable ecological and recreational value as greater reliance on groundwater resources takes place (Newman and Kenworthy, 1999), an entrenchment of the dependence on centralised supply systems such as desalination plants with inherent cost and energy requirements, and the exacerbation of 'path dependence', disincentivising and reducing the efficacy of more adaptive approaches in the future (Hurlimann and Wilson, 2018).

The diversification of water supply sources includes techniques such as greater rainwater and stormwater harvesting, and recycling of wastewater (Jegatheesan, 2018). Both rainwater and stormwater can be used locally for applications that do not require drinking water quality, including irrigation for agriculture. Stormwater can be retained as a landscaping feature, slowing the flow or runoff into receiving water bodies and/or allowing it to recharge groundwater resources (Tjallingii, 1995; Fletcher et al, 2015). These decentralised approaches to water management are not necessarily in competition with the legacy of centralised systems but can work complementarily to mutual advantage in a hybrid water supply system (Sapkota el at, 2018).

Increasing water use efficiency and/or reducing the demand for water can be achieved by applying water-saving technologies and behavioural incentives (Tjallingii, 1995), though the success of these strategies depends strongly on a fine-tuned interplay between applied technologies, governance of their implementation, user awareness and behaviour (Sharma et al, 2016). This results in difficulties in predicting the performance of these interventions and hence, often lead to their under-deployment (Hurlimann and Wilson, 2018). At a local scale, however, there have been a number of success stories in public education on water conservation, such as Victoria's 'Don't be a Wally with Water' (1984) and 'Target 155' (2008) campaigns (Low et al, 2015; Melbourne Water, 2020).

Climate change implications of urban water management

Hurlimann and Wilson (2018) identify three key areas of water-related climate change impacts and their implications on water supply and spatial planning.

An increased risk of droughts increases pressure to apply all three interventions of supply augmentation, supply diversification and demand management discussed above; they call for measures to reduce water demand in new developments, implement water sensitive urban design principles, limit development in drought-risk areas and manage increasing variability in supply.

An increased risk of heatwaves may result in increased water demand coinciding with decreased supply inflows during the affected periods, calling for infrastructure and supply adaptations to make up for the shortfall as well as for mitigation measures to enhance urban cooling effects such as the implementation of blue-green infrastructure (see below).

An increased risk of flooding from precipitation events and/or sea level rise may endanger critical water infrastructure through contamination and salt water intrusion, putting drinking water supply and wastewater treatment and disposal at risk. Mitigation strategies include the migration of urban water infrastructure and other development away from current and future areas of flood risk.

Blue-green infrastructure and Water Sensitive Urban Design

As the understanding of stormwater drainage expanded from a single-issue, technological task of conveyance, a synergistic integration of blue and green urban agendas embracing water management and landscape planning emerged (DELWP, 2017b). Harvesting stormwater as close as possible to the rain source consists of its small-scale collection and use at property level and the design of open spaces to facilitate its retention and natural groundwater infiltration (Fletcher et al, 2015). These measures lead to biodiversity, microclimatic and human amenity benefits, diversifying water supply while mitigating the effects of heatwaves and flooding. Implementing blue-green infrastructures requires a closer transdisciplinary collaboration between the traditionally separate domains of water and landscape planning, across agencies and at all levels of government (DELWP, 2017b).

Water Sensitive Urban Design aims to complement the traditional centralised water supply and disposal systems in urban areas by decentralised elements, as they meet scale constraints from urban growth, and performance constraints from extreme weather events and at-risk infrastructure (see above). Such decentralised elements include property or precinct-scale measures for drinking water conservation, minimisation of wastewater flow, quantitative and qualitative stormwater management and flood mitigation (Fletcher et al, 2015; Sharma et al, 2016). This is most commonly achieved by the implementation of bioretention systems and wetlands in urban landscaping, and by infiltration systems including aquifer storage and recovery (Jegatheesan, 2018). While some of these measures have been written into state building regulations (such as mandatory rainwater tanks or third pipes for a supplementary water supply in new residential developments), the implementation of the associated principles has sometimes been hampered by institutional fragmentation and a lack of knowledge and skills across industry, government agencies and communities in the absence of adequate documentation of the performance of implemented projects. There is also widespread uncertainty about responsibilities concerning the ongoing costs and maintenance of such facilities (Sharma et al, 2016).

Summary and recommendations

Water security has been strengthened in recent years through diversification of supply sources, notably through rainwater and stormwater harvesting and recycling of wastewater (Jegatheesan (2018). The application of Water Sensitive Urban Design (WSUD) – such as property or precinct-scale water conservation, minimisation of wastewater flow, stormwater management and flood mitigation – has reduced both water consumption and vulnerability to extreme weather events (Fletcher et al., 2015).

Planning and implementation of blue-green infrastructure requires closer collaboration between agencies responsible for water management and landscape planning, across all levels of government (DELWP 2017b). While State building regulations require installation of rainwater tanks or third pipes for supplementary water supply in new residential developments, the implementation of other WSUD principles has been hampered by institutional fragmentation and a lack of knowledge and skills across industry, government agencies and communities. There is also widespread uncertainty about responsibilities for ongoing costs and maintenance of blue-green infrastructure in development precincts (Sharma et al., 2016).

Key Recommendations

- Promote deployment of decentralised water technologies at either precinct or even property scales, supported by public education campaigns to increase awareness of long-term water conservation and cost-saving benefits.
- Build skills and knowledge on the benefits and applications of Water Sensitive Urban Design in State and local government and among regional and town planners, estate developers and the community.
- Institute a long-term and sustainable funding regime to underwrite decentralised water management solutions and infrastructures.

Adopt a whole of lifecycle approach to construction materials and waste

Solid waste and the flow of materials implied in the construction, operation and demolition of buildings and their contents have a substantial environmental and economic impact, and their management feeds back to the social makeup of a community. Like water management, waste management is not only about the final discharge and what to do about it, but rather begins with decisions in the planning process of a neighbourhood or building and does not end with providing recycling facilities (Newman and Kenworthy, 1999).

In fast-growing Melbourne suburbs, the dominant waste problem with a view to climate change impacts concerns the volume, management and disposal of construction waste. This is related to the embodied energy content of the built environment, i.e., the energy required to produce, transport and assemble construction materials, and the rate of their renewal or replacement during the life of a built structure or land use.

Construction waste and embodied energy

Building materials carry embodied energy associated to their production process, the transport effort needed to bring them to the construction site, their product lifecycle and their performance as waste material at demolition. As operational energy requirements of buildings reduce due to greater energy efficiency in building design standards and technical equipment, the material-embodied portion of energy consumption increases in relative terms (Jensen et al, 1998; Teh et al, 2019). Life cycle analysis of construction components has gained increased attention in assessing the total energy and greenhouse impact of built structures, though systematic studies specific to Australian conditions remain scarce (Iyer-Raniga and Wong, 2012).

Construction and demolition waste accounts for around one third of all waste generated in the Australian economy, and for a similar percentage of waste going to landfill (ABS, 2014; Park and Tucker, 2017). The composition of building waste is highly complex for the sheer amount of different materials used, and the compound nature of many building parts makes it difficult to separate specific components for recycling. As a result, most building waste, if used at all, is down-cycled; that is, the value of the waste is not retained.

But while the building shell usually consists of materials that are relatively simple in structure - concrete, timber, stone, bricks etc - and require relatively little energy to produce as such, they also represent the heaviest and most durable elements and therefore the largest component in embodied transport energy to and from the site. High demand on these materials occasionally results in shortages of regional supplies, and subsequently increases pressure on nature reserves for quarrying, and/or the need to carry the materials over longer distances (Jensen et al, 1998).

Conversely, it is the internal fit-out of buildings that contains most materials with environmentally hazardous ingredients and significant embodied energy from the production process. Their useful life is usually considerably shorter than that of the building shell while requiring less transport effort to move around. Thus, it would be ideal from a material-efficiency standpoint to devise strategies that make use of the building shell for as long a period as possible to minimise the need for demolition works, while working on reuse and recycling schemes for technical equipment and environmentally benign approaches to interior decoration. Virtualisation and dematerialisation are playing key roles in reducing material intensity and associated impacts. For many products there are tensions between extending life and replacement by much more efficient solutions – as long as recovery and recycling mechanisms are effective.

A whole of life-cycle approach to construction is the only way to account for the true environmental impact required to produce, transport and assemble construction materials, as well as the rate of renewal or replacement over the lifetime of a built structure. Developments in both new and established suburbs should also consider material impact and not 'lock-in' virgin material use. Since buildings can last for 80-100 years or longer and thus likely witness profound and unforeseeable changes to expectations and usage of the built environment over their life span, it is paramount – and imperative from the perspective of the precautionary principle – for long-term waste minimisation to design a building shell that is as flexible as possible to changing uses over time (Barton, 2000). Such flexibility can further be supported by enabling the building componentry to be dismantled into reusable pieces, rather than knocked down into piles of compound rubble, should major alterations or removal of the structure become necessary. With regard to the internal fit-out, the attention should be on optimising energy performance and environmental characteristics of each material used (Jensen et al, 1998). There is potential for innovative models such as the City of Brummen's (Netherlands) 'lease' construction of its Town Hall, built under a 20-year service contract and designed so it can be disassembled and the components returned to suppliers (Kiser, 2016; EC, 2017).

Reform

Park and Tucker (2017) lament that the Building Code of Australia focuses primarily on operational energy efficiency in buildings while giving comparatively short shrift to issues such as the embodied energy of construction materials or waste management at construction sites. Udawatta et al (2015) identify a need for further regulation in this respect, for example by determining minimum quotas for the reuse of materials, and a reform of financial incentives and disincentives such as landfill levies, as they consider the construction industry to be highly price sensitive.

Yuan (2013) identifies a number of challenges to waste minimisation in the construction process. These range from the obsolescence of already procured or utilised materials or building parts due to late changes of the building design to insufficient planning and resourcing for waste management, including quality assurance within the construction process and upskilling of operatives towards waste minimisation outcomes. There is a need to allocate sufficient physical space for waste management and collection of recyclable materials within construction sites, and to provide incentives towards low-waste construction technologies including prefabrication and modularity of materials.

There are also challenges to the organisational culture of the construction process, where environmental considerations sometimes compete with pressures to minimise completion times (Yuan, 2013), and where the resource efficiency incentives and priorities of construction companies do not necessarily match those of end users (Iyer-Raniga, 2019). Park and Tucker (2017) detect shortfalls in coordination and communication among stakeholders in these areas. Udawatta et al (2015) found that project managers tend to think of waste management predominantly as a technical challenge, while their work with other stakeholders shows that it is more critically an issue for human relations and communication, echoing previous findings by Crabtree and Hes (2009). As an example, Iyer-Raniga (2019) highlights the integrated, iterative collaboration process between architects, consultants and construction companies that needs to occur where good energy, material and waste efficiency outcomes are sought, and how this departs from the traditionally linear processes of project delivery between professionals. Crabtree and Hes (2009) as well as Park and Tucker (2017) report widespread attitudes among different industry stakeholders to mutually blame each other for sustainability underperformance in construction; it is imperative that such disconnect be overcome for improved outcomes. One way of fostering better shared understanding of the tasks among the diversity of stakeholders involved in the construction process is to facilitate communication and visualisation through the use of energy and resource performance tools in design and construction. Such tools also lead to better monitoring of actual performance in material efficiency, offering the opportunity to directly inform design and construction process innovations as a critical element in achieving superior outcomes from multi-disciplinary collaborations (Iyer-Raniga et al, 2014).

Summary and recommendations

The predominant waste problem presented by urban development is the volume, management and disposal of construction waste. Construction and demolition waste accounts for around one third of all waste generated in the Australian economy, with a similar proportion going to landfill (ABS, 2014). Most of the waste, if used at all, is downcycled, so its value is not retained. Rather than the traditional "hand-over" from project design to delivery, iterative collaboration between architects, consultants and construction companies can support improved resource use and waste efficiency outcomes, particularly through the use of energy and resource performance tools (Iyer-Raniga et al., 2014).

The Building Code of Australia focuses primarily on design and operational energy efficiency in buildings and gives comparatively little attention to the embodied energy of construction materials or waste management at construction sites (Park & Tucker, 2017). A good first step would be to introduce construction and demolition waste protocols as have recently been established in the European Union (EU, 2018).

A whole of life-cycle approach to construction is essential to account for the true environmental impact of the production, transport and assembly of construction materials, as well as the rate of adaptation, renewal or replacement over the lifetime of a built structure. Landfill levies need to consider the true cost of waste. The external shell of buildings can be designed to be flexible in response to changes in use over time (Barton, 2000), and building componentry can be designed to be dismantled or deconstructed into reusable pieces. Current linear processes in the building and construction supply chains need to be reconsidered and new ways explored. There is potential for innovative models such as the City of Brummen's (Netherlands) 'lease' construction of its Town Hall, built under a 20-year service contract and designed so it can be disassembled and the components returned to suppliers (Kiser, 2016; EC, 2017)

Capacity building and skills development among industry stakeholders is essential to foster collaboration styles and processes that can deliver on material efficiency and waste minimisation objectives and can be achieved through targeted education programs as well as the use of professionally facilitated performance-monitoring design and procedural tools. Rather than the traditional "hand-over" from project design to delivery, iterative collaboration between architects, consultants and construction companies can support improved resource use and waste efficiency outcomes.

Key Recommendations

- Improve waste identification, source separation and collection, supported by waste logistics and waste processing facilities.
- Support procurement systems for high class recovery of waste to ensure second and third life of materials, underpinned by a framework to ensure quality and confidence in recycled construction and demolition materials.
- Promote industry use of 'track and trace' in material use to develop and support 'material banks' that can be used for design and construction process innovations.
- Incorporate life cycle assessments of construction materials and waste management at construction sites into state-based regulations and the National Construction Code.
- Consider increases to landfill levies to reflect the true cost of waste and tax virgin material use.
- Develop training and skills to encourage sustainable management of construction waste.

Summary and Recommendations

How can Victoria's planning system respond to the challenges of the climate policy agenda, both in minimising the contributions of the built environment in Melbourne's suburbs to global heating, and in minimising the adverse effects of climate-related impacts on resource cycles, community wellbeing and the resilience of neighbourhoods and infrastructures?

In the introduction to this briefing paper, we stated three broader agenda items for the Victorian planning system to achieve the step-change required to address the climate change mitigation and adaptation challenges in Melbourne's suburbs:

- Build the capacity at both state and local government level to take a more proactive role in formulating strategic, long-term objectives for a low-carbon, risk-mitigated urban environment;
- Establish suitable regulatory mechanisms over and beyond traditional planning control and mediation processes to implement these;
- Provide leadership for public and private stakeholders to build the skills, community support and industry capacity for transformative change.

How do these goals manifest in each of the seven themes addressed in this briefing paper?

Urban form

The dominant low-density, functionally disintegrated settlement typology in Melbourne's suburbs leads to high embodied and operational energy consumption, both stationary and through transport, and a continuing high rate of rural to urban land conversion. Planning, regulatory and taxation agencies at all levels of government need to collaborate to develop new tools in collaboration with industry and communities that foster urban intensification in established middle and outer suburbs while capitalising on emerging social needs and changing market trends in favour of higher-density neighbourhoods, and reorganise the process of greenfield and brownfield development with a view to delivering better sequenced new urban areas with greater functional integration and housing diversity.

Transport

Both climate adaptation and mitigation in suburban areas require a reduction of car dependence among residents, visitors and employees. Urban intensification in established areas and the delivery of more 'complete' greenfield suburbs need to be accompanied with programs to improve the public realm and make walkability and active transport the primary local transport priorities. Public transport agencies need to introduce a layer of proactive, multi-modal network planning and explore new planning and funding tools to facilitate the implementation of additional rail infrastructure in both new and established suburbs, and the rollout of a second, medium-capacity public transport tier across middle and outer Melbourne drawing on various technologies as suitable in each local context (light rail, trackless tram, bus rapid transit). New modes of shared, autonomous and micro-mobility with the potential to further reduce dependency on private cars will likely require public support to achieve broad rates of deployment in suburban areas.

Biodiversity and biophilic urbanism

Biodiversity assets in Melbourne's suburban and peri-urban areas are under the combined stress of ongoing conversion of land to urban uses and of climate change-related effects such as increasing droughts, heatwaves, bushfires and high precipitation events. Preserving and improving the quantity and quality of natural environments in and around human settlements requires a new perspective on the planning process with a view to maintaining (in newly urbanised areas) and restoring (in established urban areas) as much as possible the local richness and functionality of natural energy, water and nutrient cycles. Biophilic urbanism principles as part of a renewal agenda for established suburbs and the direction of new urban development to land with low biodiversity value while protecting high-biodiversity areas and their connections will assist these goals and needs to be instituted in planning directives.

Bushfire risk

The increasing frequency and severity of bushfires impacting human settlements call for a new layer of risk management especially in peri-urban areas where a spatial patchwork of natural environments and rural residential development has emerged in the absence of a comprehensive planning framework. Planning and regulatory agencies need to instigate a more systematic regime that takes into account the cumulative effects of individual land use decisions in bushfire risk areas and is furnished with the authority to make broader planning decisions on the basis of the precautionary principle. An increasing proportion of the population is being exposed to bushfire risk, and this increases the risk of failure of energy supply and other types of infrastructure. Additional capacity and innovative solutions will be needed to provide services during exteme events and during recovery. Alternative solutions may be required to increase resilience.

Energy management

A proactive approach is required on behalf of planning and regulatory agencies to direct and incentivise urban energy efficiency improvement, digitalisation and the transition from centralised, fossil fuel-driven energy supplies towards a greater role for distributed, renewable electricity generation. This includes incentives, development of supply chains, empowerment of consumers through information, consumer rights and enhanced equity, ambitious renewable energy targets, including at the local scale, set by the policy process, and a reorientation of investment in expanding, upgrading or maintaining electricity grid infrastructure that, where applicable, prioritises the needs of the emerging distributed supply system over those of the old centralised supply system. The uptake of decentralised energy generation and storage equipment at the neighbourhood scale will require specific programs targeted at developers and/or community initiatives.

Water management

The policy and regulatory environment in Victoria are already broadly supportive of a transition away from traditional, centralised urban water supply and disposal systems that are under strain from urban growth-related capacity and performance pressures, exacerbated by the increasing variability and intensity of drought, precipitation and heatwave events associated with climate change. The key tasks for planning and regulatory agencies to further this transition towards diversified water supply/disposal and increased water conservation through the deployment of decentralised technologies are to facilitate better skills and knowledge sharing with stakeholders, and to institute more reliable funding regimes for decentralised water management solutions and infrastructures.

Construction material and waste management

It is critical to review and strengthen financial incentives and disincentives around waste generation in construction, through mandatory on-site performance standards, public support for recycling schemes of construction waste, and sufficiently high fees to as much as possible discourage landfill as a waste disposal solution. Capacity building and skills development among industry stakeholders is essential to foster collaboration styles and processes that can deliver on material efficiency and waste minimisation objectives and can be achieved through targeted education programs as well as the use of professionally facilitated performance-monitoring design and procedural tools. Rather than the traditional “hand-over” from project design to delivery, iterative collaboration between architects, consultants and construction companies can support improved resource use and waste efficiency outcomes.

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RMIT UNIVERSITY

Further Information

Centre for Urban Research
RMIT City campus
Building 8, Level 11
124 La Trobe Street
Melbourne VIC, 3000
Australia

T: +61 3 9925 0917
E: cur@rmit.edu.au

www.cur.org.au

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