"Planning and Implementing Living Infrastructure in the Australian Capital Territory" Final report

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Executive summary

This report has been prepared for the CURF Living Infrastructure Project. The project focuses on generating knowledge to support delivering of innovative, high-quality living infrastructure as part of Canberra's urban renewal and development processes. Through a combination of reviewing and synthesising the literature and consulting with key stakeholders the research has identified a number of key themes and issues relevant to Canberra. These are summarised below:

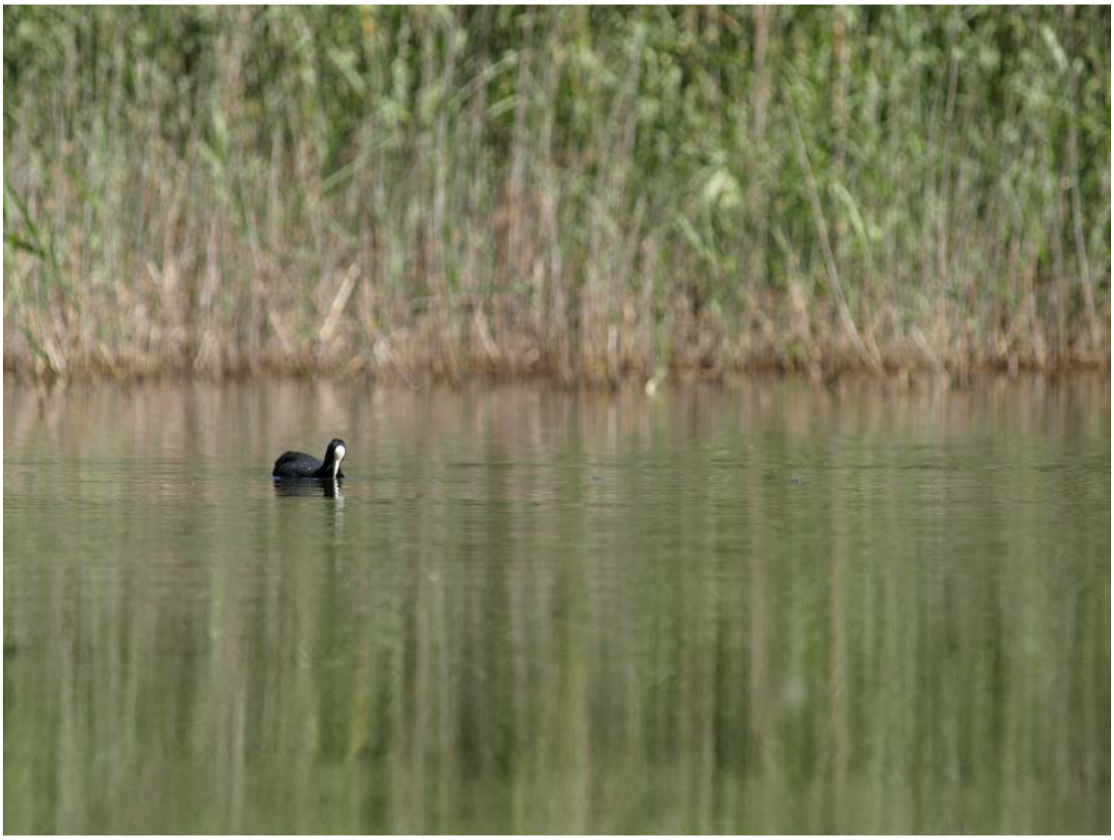
With reference to integrated planning of living infrastructure, the CURF research found that:

1. Living infrastructure initiatives focus on transformation of the forms and functions of cities while also building human and institutional capacities.
2. Strong synergies arise from integrating urban and conservation planning with decarbonising and innovation strategies. Integrated planning approaches harness these synergies to achieve multiple social, economic and environmental benefits.
3. Given the substantive governance and integration challenges, consideration needs to be given to the institutional arrangements required for long term commitments to living infrastructure.
4. Criteria for success include institutional and political commitment, capacity for integrated planning and active community participation.
5. Technical and institutional complexity can constrain living infrastructure programs, requiring concurrent commitments to integrated planning.

In terms of opportunities for the ACT, the CURF research found that:

6. Canberra has an opportunity to become a centre of innovation in living infrastructure (LI) through integrated planning for urban climate adaptation.

7. Successful LI strategies emphasise the cultural aspects of innovation. Canberra has the potential to be a catalytic sponsor for innovation through demonstrating transformative adaptation options.
8. Cities have traditionally been centres of innovation. Comprehensive climate adaptation strategies focus on reducing emissions, increasing sequestration and building technical and social capacity for innovation. To this end, Living Infrastructure strategies would be enhanced through research and development (R&D) and educational partnerships.
9. Through an integrated Living Infrastructure program the ACT could enhance expressive, technological and cultural capability for adaptation.



In terms of effective consultation, the research identified that:

10. Consultation and participatory planning methods are central to successful urban strategies. Broad partnerships typically build constituencies for change. Deliberative and participatory techniques like scenario planning help build capacity by empowering people to prepare for transformative futures.

11. Participatory scenario planning can be useful for exploring adaptation options and for building support by engaging people in exploring possible futures.

The research found many opportunities for integrating water into living infrastructure:

12. Living infrastructure reconceives of stormwater as a resource that can enhance amenity in wetlands and forests.
13. A wide range of viable strategies and proven technologies enable stormwater to be redirected towards biologically productive uses, including through ponds, dams, water gardens and soakage pits.
14. A key issue for Canberra is the extent to which comprehensive water sensitive urban design strategies are adopted in new and old suburbs.
15. Canberra faces the challenges of adapting to changing rainfall patterns, which are predicted to bring more intense rainfall events with increased risk of flooding, as well as longer and more intense droughts. Living infrastructure will need to be designed with these changes in mind. A program of expanding urban stormwater storages and flood retention wetlands could assist in reducing drought and flood risks and increase urban water reuse.
16. Good practice in water sensitive urban design minimises risks associated with changing rainfall regimes and generates a range of complementary co-benefits.

Risk reduction is a key design consideration in living infrastructure programs:

17. Well-designed living infrastructure plays key roles in reducing risk. Of particular relevance to Canberra are bushfire risks because of the catastrophic impacts of fires at the bushland–urban interface. Other risks of significance include urban heat stress and more intense storms and flooding.
18. There are a range of planning, land use and vegetation strategies that can be used to minimise the risks and impacts of wild fires. Strategic fuel-

breaks could be used to minimise impacts of fire, but integrated approaches to planning and land management are required.

19. In terms of living infrastructure, fuel reduction zones and bands of deciduous trees on the bushland margins may be useful for reducing fire intensity and slowing fire spread because most deciduous trees have lower flammability than eucalyptus and pine species, steaming rather than exploding when heated by bushfires. Further research and modelling is justified due to a paucity of literature on these kinds of approaches to integrated fire risk reduction applicable in South East Australia.

Urban forests and biodiversity conservation are integral to living infrastructure:

20. Canberra is fortunate in having a long-standing commitment to urban forestry. It is now well-placed to capitalise on growing international interest in urban forestry. There is a significant opportunity to cement Canberra's place as a global leader in urban forestry through sponsoring engagement, education, scholarship and tourism that builds on historical plantings, the national arboretum and the botanic gardens.

21. Many cities are aiming to enhance biodiversity conservation but achieving biodiversity conservation goals requires the application of ecological theory in targeted and applied strategies of adaptive management.

Finally, the research identified that greater use of planning guidelines and design principles may enhance the quality of planning decisions:

22. Numerous studies indicate the high value of ecosystem services in urban areas. A critical issue for supporting better planning decisions is being able to broadly quantify ecosystem service benefits arising from specific options under consideration. Use of outcome focused guidelines or guiding design principles may be more effective than further detailed valuation studies, given the intrinsic uncertainty about ecological processes and the fuzziness of valuation metrics.

1. Introduction

The CURF Living Infrastructure project is focused on generating knowledge and building capacity for delivering integrated, innovative, high-quality living infrastructure as part of Canberra's urban renewal processes.

The aim is to ensure that Canberra is an even greener city as a result of urban renewal, with a focus on the ACT Government's City and Gateway Urban Renewal Strategy.

Living infrastructure is giving expression to a global 'movement' focused on enhancing urban systems. Living infrastructure can be defined as biological and ecological systems installed and managed in and around cities for multiple purposes including:

- functional effects – like cooling
- ecosystem services – like carbon sequestration, and
- risk mitigation – like reducing impacts of droughts or fires.

In this report we use "living infrastructure" to refer to the integration of trees, shrubs, grass and open spaces (green infrastructure), with rainscapes and waterways (blue infrastructure) and soils, surface and man-made structures (grey infrastructure) that are designed to deliver multiple social (people) environmental (place), and economic (prosperity) services to urban communities.

This report has been prepared based on surveying and synthesising knowledge of living infrastructure and refined on feedback from stakeholders and reviewers. The literature reviewed identified major opportunities and critical issues for planning and implementing living infrastructure initiatives.

This report summarises a number of key themes, opportunities and issues relevant to Canberra, emphasising five interrelated themes:

1. The need for integrated planning of living infrastructure as part of climate responsive cities[1] including through ensuring governance institutions and communities are engaged (Anguelovski 2014; Carmin 2013; Groot *et al* 2015) (sections 2 and 3).
2. Rethinking and redesigning water systems to optimise 'blue infrastructure'[2] opportunities to achieve urban amenity, livability and climate resilience (Wong 2006; de Haan *et al* 2014; Ferguson 2013a) (section 5).
3. Planning to reduce risks and hazards like extreme heat, flooding and fire (for example, Hunt and Watkiss 2011) (section 6).
4. "Urban greening" to achieve living carbon along with other beneficial roles of urban vegetation through the integrated use of street trees, urban forests, open spaces, gardens, vertical green walls and planted roofs (Li *et al* 2005; James *et al* 2009) and including revegetation to enhance biodiversity conservation (Navarro and Pereira 2012; Goddard *et al* 2010) (section 7).
5. Use of planning guidelines to ensure urban development decisions maximise economic, community and ecosystem services and the co-benefits of living infrastructure (section 8).

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[1] The term climate responsive cities is used to refer to cities that are actively responding to climate change challenges through efforts to both mitigate and adapt, with living infrastructure playing key roles in both types of responses.

[2] Waterscapes and systems are often referred to as 'blue' environments but in Australia with our turbid waters and dry wetlands waterscapes are more generally murky brown or the grey greens and olives of water plants.

2. The planning context in Canberra

There are major planning initiatives occurring in Canberra to design and create a more sustainable urban future. These include introducing a rapid transit system with light rail, connecting the city to the lake, and significant urban renewal programs. These major programs are also being implemented with the impacts of climate change in sight. The City and Gateway Urban Renewal Strategy and the redevelopment of the light rail corridors present tremendous opportunities to enhance the living environment by integrating leading practice in "living infrastructure".

Planning for climate change is a significant driver in Canberra and the city can rightly claim to be a climate responsive city[3] because it is actively responding to climate change challenges through its efforts to both mitigate and adapt to

[3] The term climate responsive cities is used to refer to cities that are actively responding to climate change challenges through both efforts to both mitigate and adapt, with living infrastructure playing key roles in both types of responses.

climate change. The ACT is a leader on action on climate change, focusing on reducing greenhouse gas emissions through a number of strategies outlined in the ACT Climate Change Strategy. The primary target is 100 per cent renewable electricity by 2020, via solar and wind energy as well as a complementary program on energy efficiency. These actions will have implications for any future design of the built environment – new or renewed.

The ACT has prepared a companion ACT Climate Change Adaptation Strategy: living with a warming climate. It includes seven themes – disaster and emergency management; community health and wellbeing; settlements and infrastructure; water; natural resources and ecosystems; innovation and integration; and monitoring and evaluation. A key strategy is to 'Develop and implement a strategy to enhance living infrastructure in the Territory, including targets for urban tree canopy cover' (ACT Government 2016).

Although this scoping study aims to be relevant for Canberra as a whole, it is initially focused on the urban renewal triggered by the CMLR (Capital Metro Light Rail) and the broader City and Gateway Urban Renewal Strategy This offers an opportunity to focus on a well-defined transit corridor and surrounding precincts as a case study for creating an even greener city through the urban renewal process. The Inner North and Flemington Road corridors can become a living laboratory on which to build a better, action-oriented knowledge base to achieve this vision. Such a study would build on the different characteristics of the two segments of the CMLR first stage corridor that offer interesting contrasts in terms of green infrastructure. The inner north/Northbourne corridor is dominated by existing urban development, both suburban and denser urban form, flanked by two large nature reserves. The Flemington Road to Gungahlin sector has considerable more greenfield potential, both for built infrastructure and for living infrastructure – parks and corridors.

A primary aim of living infrastructure is to store more carbon in the City and Gateway Urban Renewal precincts than before the urban renewal process was undertaken. That is, by 2050 the precincts will be storing more carbon than in

2016 due to smart tree planting and development of more living infrastructure (street trees, parks, hedges, plantings, green walls, etc).

The planning process for the City and Gateway Urban Renewal project also provides the integration mechanism for placing this study on living infrastructure within the broader urban renewal process. This is particularly important in terms of planning for built infrastructure (such as residential and commercial buildings), which, for example, should be:

1. planned and built allowing space for living infrastructure
2. be energy and water sensitive, and
3. be sited to maximise potential for passive and active solar energy.

In short, planning should focus on *green precincts*, that combine the beneficial attributes of built and living infrastructure.

As discussed above, the ACT Government has a well-developed climate adaptation strategy. Living infrastructure plays an important role in adaptation including:

1. through the role of shade trees and other living infrastructure in cooling, reducing the impacts of extreme heat, and minimising the urban heat

island effect as well as dealing with heatwaves and hot days more generally

2. adapting to changing rainfall patterns that could bring more intense rainfall events and increase the risk of flooding, as well as longer and more intense droughts. Living infrastructure can play an important role in water sensitive urban design aimed at minimising the risks associated with such changes in the rainfall regime, and
3. through responding to increasing high bushfire danger weather, which will rise further, putting especially vulnerable districts of the city and surrounds at higher risk of bushfire damage. This threat will need to be accounted for in designing living infrastructure that can deliver climate adaptation and amenity benefits without enhancing bushfire risk.

The benefits of living infrastructure are enhanced by good planning and design and integrated approaches. The literature identifies five dimensions to integration that are critical to the success. These are that programs:

1. adopt genuinely integrated approaches that engage across multiple scales and functions of governments

2. engage and involve communities in the visioning and practical aspects of planning and managing living infrastructure programs
3. integrate technical aspects (technical, educational and valuation) with policy aspects and long-term institutional support
4. recognise and incorporate the symbolic and cultural dimensions as well as the technical and material aspects of managing the urban environment, and
5. commit to ongoing adaptive learning, R&D and education.

These five dimensions will be critical to the success of the strategies described below.

3. Urban amenity, individual and community health and wellbeing

3.1 Introduction

Incorporating well-designed living infrastructure in the ACT's urban renewal will ensure greater physical, mental, community, ecological and economic health, and livability. Many studies show that human health and wellbeing, including cognitive function and mental health, are enhanced by frequent contact with urban nature (Standish *et al* 2013). Well-designed living infrastructure enhances urban amenity and delivers good social outcomes by providing places for people to meet and enjoy social interaction, as well as actively enjoying urban ecosystems.

Living infrastructure requires greater human involvement than 'hard' infrastructure – like roads and bridges – but as a result, living infrastructure emphasises the human relationships and social dimensions of living cities. Given these relational dimensions, living infrastructure strategies need to focus on community engagement and involvement (Benedict and McMahon 2006; Archer *et al* 2014; Picketts et al 2013; Philho 2010; Moser and Pike 2015; Sheppard 2015).

3.2 Cultural, political and expressive roles of cities in adaptation

Critically important is the recognition that cities have important symbolic and culturally expressive functions. Through their structure, layout and design cities, especially capital cities, have important symbolic or representative roles that exceed the sum of their monuments and institutional buildings (DeLanda 2006).

Responses to climate change need to be integrated into wider processes that mobilise citizens and civic institutions (Anguelovski *et al* 2014; Carmin *et al* 2013) and into future-orientated processes that build capacity for anticipation in socio-ecological systems (Boyd 2015). Therefore, in this era dominated by concerns about climate change, Canberra's adoption of green or living

infrastructure could play significant roles in providing inspiration, evidence of commitment to stimulating innovation and smart designs as well as making the city more livable and functional on many dimensions. Any Living Infrastructure strategy adopted needs to recognise Canberra's cultural and intellectual roles as the national capital, building on its significant political, symbolic and culturally expressive functions.

The cultural and symbolic dimensions may be less tangible but are still critically important given that cities are socio-ecological systems in which knowledge, politics and imagination play critical roles in shaping them (Amin and Thrift 2002; Heynen *et al* 2006).

3.3 Urban natures as novel co-evolved ecosystems

Urban ecosystems provide many cultural, educational and recreational opportunities and produce a wide range of ecosystem services (Bolund and Hunhammar 1999). Enhancing the cultural appreciation and experiential value of urban natures is emphasised as one of the many benefits of living infrastructure (Standish *et al* 2013).

Biodiversity conservation and ecosystem services are integral to functioning urban systems (Andersson *et al* 2014). Anderson *et al* found that diverse uses of public spaces contributes to the biodiversity conservation and the functioning of urban and regional ecosystems, with sporting facilities and plots used for food production providing benefits to both humans and other organisms.

Cities can usefully be conceived of as evolving assemblages of intertwined cultural, material and ecological elements that emphasise multiple relationships and networks operating at multiple scales (Marcus and Saka 2006; Anderson and McFarlane 2011; Fuller 2013; McFarlane 2011). These assemblages are co-evolving socio-ecological systems (Folke *et al* 2002; Gual and Norgaard 2010). Urban natures are human created in two senses. Firstly, all conceptualisations of nature are cultural constructs (Castree 2014), and secondly urban natures tend to exist within and in relation to the constructed urban systems that are inherently materially and socially complex, politicised environments (Heynen *et al* 2006).

Conceiving of cities as co-evolving assemblage assists in framing strategies that support the co-production of urban areas. These actively engage citizens and communities in shaping and stewarding their environments. Active co-production of urban areas results in stewards of urban ecosystems who are involved in shaping and protecting urban natures (Andersson *et al* 2015). Participatory processes support the co-production of strategies, ensuring commitments to implementation (Chapin *et al* 2009; Turner *et al* 2015). Participatory planning engages people in initiative focused on achieving broad societal goals (deHaan *et al* 2014) and establishes cooperative, multi-disciplinary networks empowered to deliver on co-produced strategies (Chapin *et al* 2009; Turner *et al* 2015).

Participatory approaches need to focus on setting forward-looking planning objectives because idealised pre-development benchmarks for conservation may be redundant. With the changing climate of the Anthropocene, the historic

definitional boundaries of what is human and natural are breaking down (Castree 2014a) requiring a rethinking of the ways in which biodiversity conservation or restoration objectives are set (Dunlop and Brown 2008; Alexandra 2012).

In summary, it is critical that planning objectives for living infrastructure and urban ecologies recognise the novel co-produced nature of urban ecosystems and focus on setting forward-looking planning objectives.

3.4 Diversify participation and utilization strategies

Engaging people broadly in participatory planning generates ideas and builds support for the adoption of living infrastructure programs. Many studies emphasise the critical role of engaging people, ensuring participation and making sure citizens, communities and practitioners are involved (Benedict and McMahon 2006; Archer *et al* 2014; Picketts *et al* 2013; Philho 2010; Moser and Pike 2015). Community engagement in urban planning can be supported with techniques that support visualisations of different future options (Sheppard

2015; Senbel and Church 2011).

In their review of the literature on the human health and ecosystem benefits of living infrastructure, Tzoulas *et al* (2007) found substantive evidence of the beneficial health impacts and that these are enhanced by diverse participation strategies for public involvement. Opportunities include providing options for active sports, passive recreation and for urban food production – community gardens, veggie plots, urban farms etc - due to the health and community benefits arising from community food gardens (Wakefield *et al* 2007). It is noted that clarity regarding the governance, access and entitlement arrangements to food production areas is critical to their success. Many successful examples of community gardens exist in urban areas, often reclaiming wasteland like CERES Community Environment Park (see http://ceres.org.au/) or through repurposing land previously used for other purposes like The Vegout Community gardens in St Kilda which was formerly a bowling green (https://vegout.org.au).

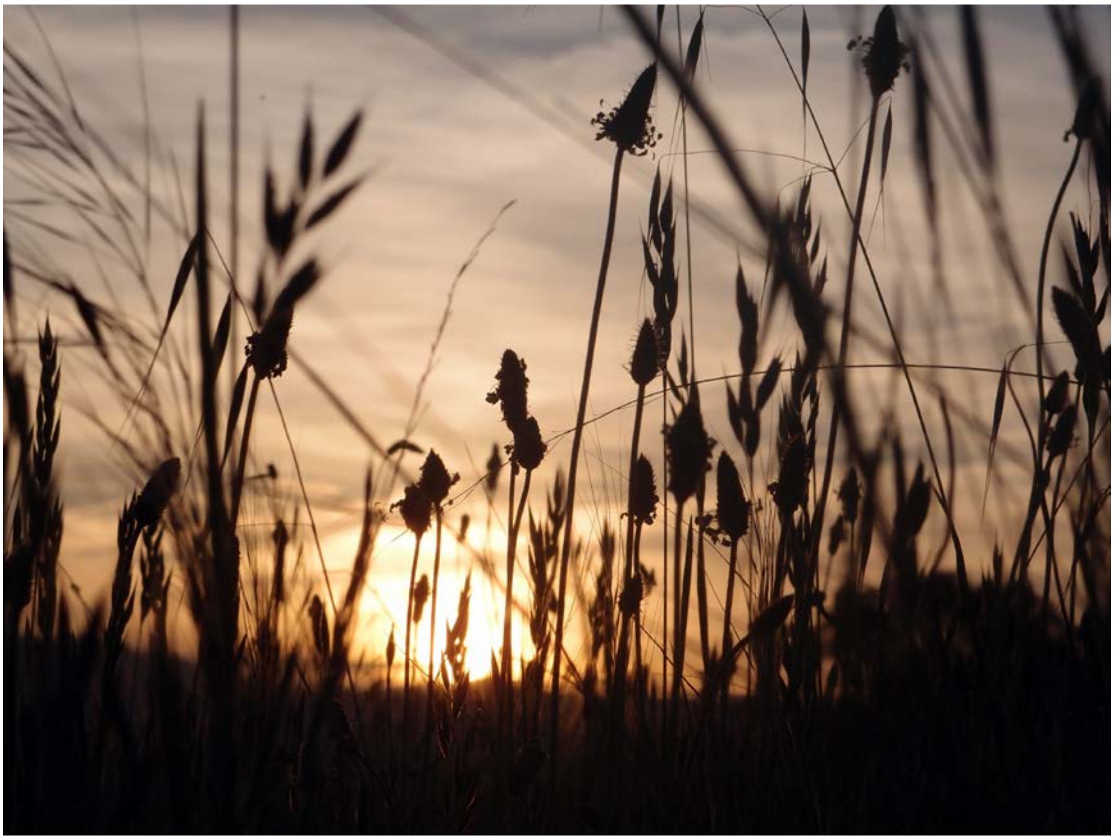
Citizen science provides another opportunity for involvement. Australia has demonstrated the value of building networks of citizen scientists and environmental stewards – for example, water and frog watcher (Campbell 1994; Alexandra *et al* 1994). ACT Living Infrastructure programs could build on this by involving people as active participants in monitoring, management and care.

In summary, the literature supports diverse participation strategies that encourage ecosystem and human health. Opportunities for actively involving citizens include through facilitating the formation or revitalisation of networks of environmental stewards (for example, landcare and friends of parks group) and citizen scientists, and as well as through supporting urban community food gardening initiatives which introduce more diverse land uses and enhance community wellbeing (Wakefield *et a*l 2007).

4. Climate responsive cities

4.1 Living infrastructure, cities and climate responses

Well-designed living infrastructure is an essential component of effective climate mitigation and adaptation strategies for cities. This section reviews literature on living infrastructure, drawing on the many approaches that are being planned and implemented in cities globally (see, for example, Funfgeld 2010; Groot *et al* 2015; Anguelovski *et al* 2014; Govindarajulu 2014).



Cities are central to global climate responses undertaking a vast global program of experimentation (Broto and Bulkeley 2013). ICLEI – Local Governments for Sustainability estimates that over 1500 cities, towns and regions have committed to integrated responses including programs of living infrastructure (http://www.iclei.org). This wealth of activities is contributing to the generation of an extensive literature reviewed by Broto and Bulkeley (2013), Leal Filho (2010), Carmin *et al* (2013) and Hunt and Watkiss (2011). This literature spans the material, operational, strategic, institutional, engagement and risk aspects of

urban climate adaptation and mitigation strategies.

Climate strategies focus on reducing emissions and increasing sequestration whilst also building capacity for climate responses. Innovation and capacity building are central features of many strategies. In this way, cities are doing what cities have historically done: being centres of innovation where the ferment of new ideas sponsors innovation and the development of the technological and cultural capability for adapting to changing circumstances (DeLanda 2006; Attali 2009; Otto-Zimmermann 2012).

Broto and Bulkeley (2013) reviewed over 100 examples of cities with climate strategies finding that the majority were focused on reducing carbon emissions through:

1. retrofitting existing building stocks (see Ma *et al* 2012)
2. improving transport systems, and
3. improving energy production systems through renewable energy or converting to lower emitting energy sources or technologies (Fischer and Newell 2008; Meinshausen *et al* 2008).

Living infrastructure can also contribute through:

1. lowering energy used for heating and cooling through well sited vegetation (shade and shelter)
2. reducing urban heat island effects through the cooling effects of vegetation and water bodies (Chen *et al* 2006; Žuvela-Aloise *et al* 2016), and
3. sequestering more carbon in urban areas (for example, MacPherson *et al* 1994).

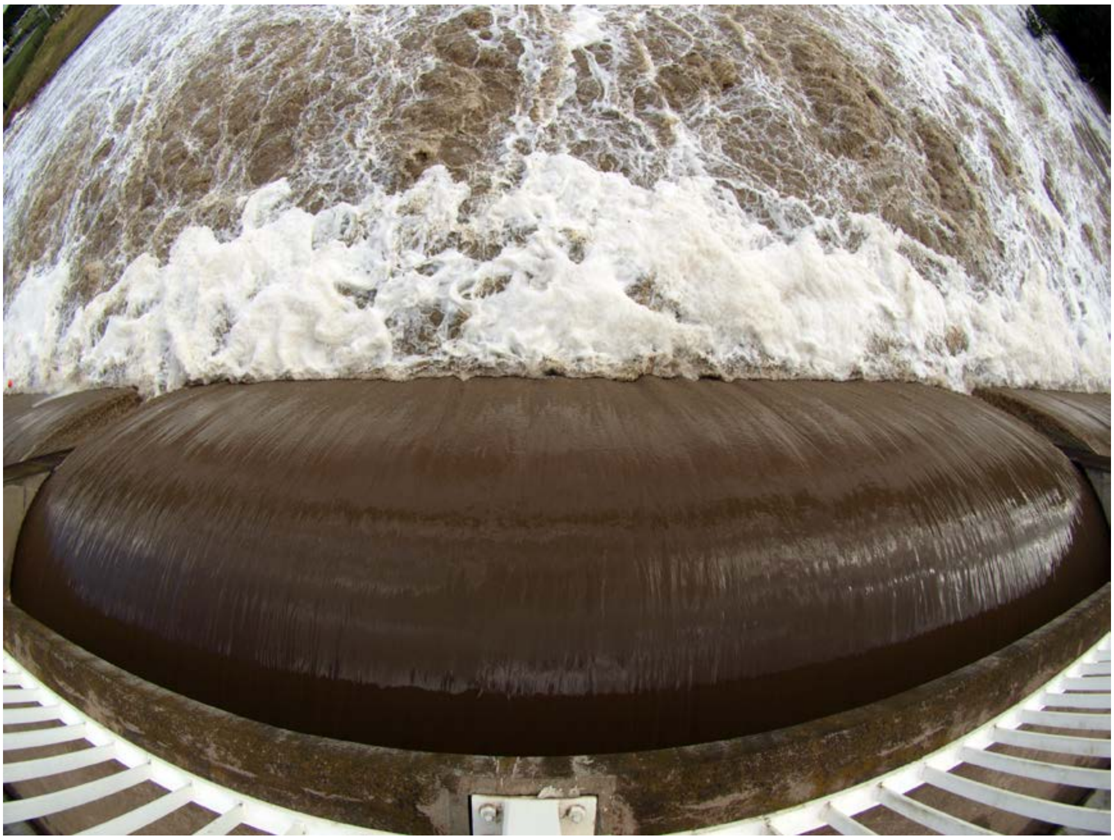
Despite these significant opportunities, climate adaptation remains a major challenge for integrated assessment and planning (Anguelovski *et al* 2014). This includes the challenges of science–policy integration (Groot *et al* 2015; Jasanoff 2004) because adaptation spans multiple disciplines and policy responsibilities. Planning and research for urban climate responses tends to occur in four related themes with corresponding disciplinary dimensions:

1. **The planned city** – adapting the physical layout of cities, for example, through urban renewal and intensification. The literature here is mostly from planning and urban design perspectives (see for example Gill *et al* 2007; Measham *et al* 2011; Wilson 2006)
2. **The decarbonising city** – adapting material and energy processes critical to city functions, for example, transport, buildings and the stock and flows of energy, goods and materials. This tends to focus on the technologies of changing energy systems and reducing emissions (Broto and Bulkeley 2013)
3. **The innovative city** – the city as a forum or sponsor for innovation and learning about adaptation, including through R&D, community engagement, pilot projects and the formation of catalytic groups. This work tends to focus on the sociology of change, the resilience and geography of cities, including as assemblages of material and cultural components (for example, Bettencourt *et al* 2007; Anguelovski and Carmin 2011; Leichenko 2011), and
4. **The living or biophilic city** – by investing in living infrastructures these cities aim to achieve multiple ecosystem service benefits and biodiversity conservation (Andersson *et al* 2014), including through parklands and urban reforestation (Young 2011), the greening of buildings and built environments (Dover 2016) and reconfiguring urban hydrology to achieve more water sensitive cities (Wong 2006; Ferguson 2013a).

Given these multiple dimensions and perspectives, there are strong rationales for integrated planning approaches focused on achieving multiple benefits (Anguelovski *et al* 2014). Ecosystem services provide one conceptual framework for thinking about integrated approaches (Bolund and Hunhammar 1999; Nelson *et al* 2009; Gómez-Baggethun and Barton 2013), as do planning and decision guidelines for technical and social integration (Govindarajulu 2012; Henstra 2012).

The research also emphasises the political and multi-scaled challenges of ensuring institutional support, with numerous studies identifying substantive

governance and integration challenges (Anguelovski *et al* 2014; Carmin *et al* 2013). For example, Funfgeld (2010) identifies several constraints to integrating climate adaptive practices into planning and development processes, including difficulty integrating and applying scientific information and unsuitable governance frameworks.



Climate adaptation is open to multiple framings (Miller 2000 and 2001; Head 2010) being integrated into diverse policies like disaster risk reduction (Begum 2014; Grove 2016), water, food and energy security (Allouche *et al* 2014; Loftus 2014) and urban policies, strategies and plans (Broto and Bulkeley 2013; Anguelovski *et al* 2014; Govindarajulu 2014).

In summary, living infrastructure offers tangible, physical manifestations of wider adaptation strategies that aim to transform cities and build human and institutional capacities to do so. Living infrastructure is more than a technical or technocratic planning challenge and needs to be understood in terms of transitions towards meeting societal needs for sustainability (deHaan *et al*

2014). As such, the symbolic, cultural and relational dimensions are central and equally critical to success as the technical and material dimensions.

4.2 Transformative adaptation – a strategic goal for cities

Climate change adaptation is now embedded as a normative goal in many national and regional strategies and its study and evaluation has become a well-established research field (see, for example, Wilby and Dessai 2010; McGray 2007; Burton 2009; Waters *et al* 2014; Biesbroek *et al* 2014; Juhola *et al* 2011). Many studies emphasise the importance of understanding the framings and underlying conceptualisation of adaptation (Füssel 2007; Eriksen *et al* 2015; McEvoy *et al* 2013; Head 2010).

A key conceptual distinction is between incremental and transformational adaptation (Park *et al* 2012; Howden and Rickards 2012). Cities face a range of constraints to transformative adaptation, including institutional complexity, fixed long-lived infrastructure, incremental planning and development processes with diffuse responsibilities across multiple governance processes and uncertainty about future climate impacts (Carter 2007; Funfgeld 2010). However, cities are also sources of innovation and experimentation (Broto and Bulkeley 2013) and are establishing networks for exchange of ideas and systems of innovation (see http://www.iclei.org).

The literature on transformations emphasises that responsiveness to new challenges, circumstances and knowledge is central to adaptive capacity (Alexandra 2012; Pahl-Wostl 2002; Rickards *et al* 2014; Boyd 2015). The need for the adoption of apparently radical change focused on sustainability solutions is supported by the extensive literature in the field of sustainability science (Jerneck 2011; Miller *et al* 2014; Pahl-Wostl *et al* 2008) and by recent global initiatives like Future Earth (http://www.futureearth.org/) including its Australian manifestation based at the Academy of Sciences in Canberra (http://www.futureearth.org.au).

Debates about how to shape cities are debates about how to shape the future and are therefore inherently political (Swyngedouw 2011; Fuller 2013; Appaduri 2013). Debates about urban futures and appropriate climate responses are inevitably rich in cultural symbolism and scientific representations because science contributes to the co-production of both knowledge and order (Jasanoff 2004) embedding normative framings and institutional settings (Sarewitz 2004; Miller 2001). Therefore, climate responses span issues well beyond the technical challenge related to adoption of specific technologies. Furthermore, specific technologies, human organisations and cities should not be conceived of separate entities: instead it is more useful to conceive of these as ensembles of related activities (Orlikowski 2008).

Broad-based urban initiatives develop pathways towards adoption of solutions that aim to meet societal needs (deHaan *et al* 2014) – but who or what processes are used to determine these needs and the preferred ways to deliver them (Fuller 2013)? In planning or policy disputes there are claims and counterclaims for legitimacy, recognition and resources (Fuller 2013; DeLanda 2006) about

preferred futures. Those with common views tend to form policy coalitions advocating certain positions (Hajer 2005). Such disputes are fundamentally arguments about the nature of the public good (Fuller 2013) based on underlying values and worldviews (Dryzek 2012). Politically and institutionally complex processes frame policy problems (Bachhi 2009; Dore *et al* 2012). These framings constrain ways of solving them, either through negotiation (Dore *et al* 2010; Saravanan *et al* 2009) or political arbitrations (DeLanda 2006; Sarewitch 2004). These arbitrations help to constitute new realities by endorsing specific plans, policy and investments in physical and social infrastructures that re-shape the realities of daily practices. For example, the introduction of mass urban transport systems fundamentally altered the physical forms and functional operations of industrial cities altering people's daily lives (DeLanda 2006). In effect these kinds of changes help constitute new cities, in terms of their forms and functions, and the beliefs, expectations and activities of those living and working within them (Grimm *et al* 2008) forming the historic and cultural platforms (and expectations of normality) on which subsequent decisions are made.

With Canberra conceived of and constructed as a largely car-based garden city, there are now tensions about the kinds of choices that will give Canberra a desirable future. Difficult choices about balancing the possible with the feasible are often constrained by preconceived ways of thinking (Rickards *et al* 2014). Participatory foresighting methods can be used to stimulate constructive dialogues on pathways to preferred futures (Vervoort *et al* 2015). These methods have been defined as creative forms of "world making" because they work to make assumptions explicit, focusing attention on pathways and practices needed to realise preferable futures (Vervoort *et al* 2015).

Successful social innovations are typically co-produced by broad partnerships (see, for example, Campbell 2005; Campbell 2010; Godden *et al* 2011). These build constituencies for policies that "address practical sustainability problems by facilitating the integration of the human and biophysical sciences in a systems approach" (http://www.futureearth.org.au). Deliberative governance,

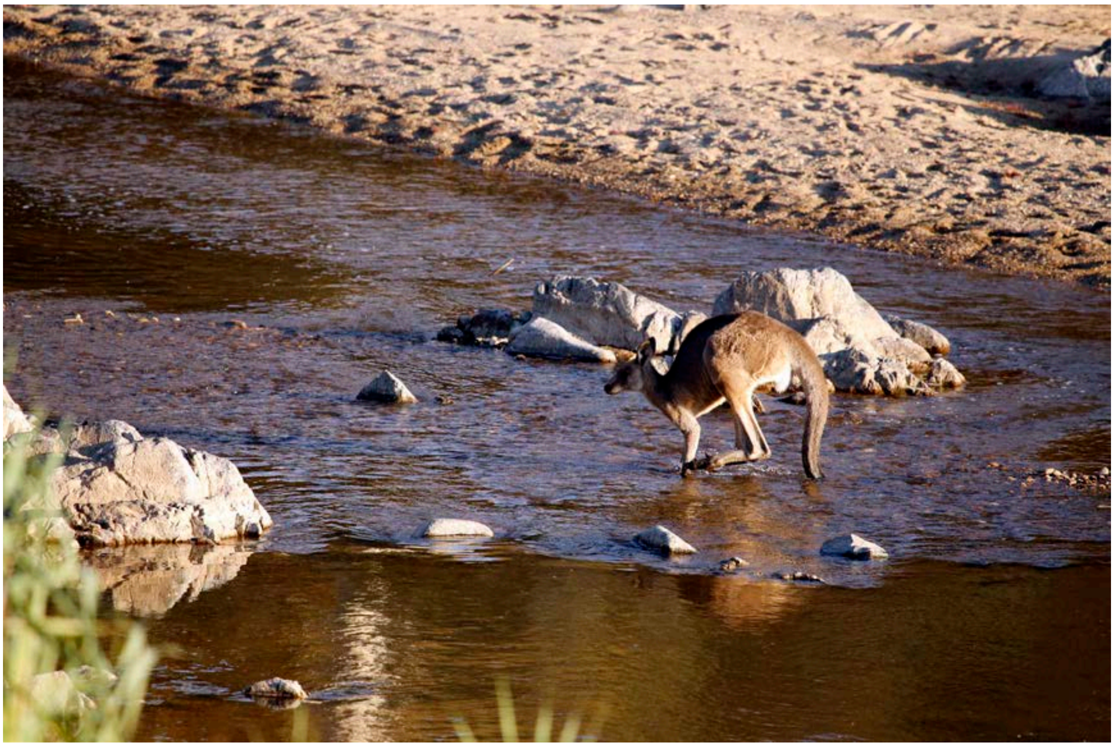
participatory management and the use of heuristic tools like scenario planning can help build capacity by empowering people prepare for transformative futures (Pahl-Wostl 2002; Walker *et al* 2002; Folke *et al* 2002; AAS 2012; Rickards *et al* 2014).

Transformative approaches are often based on rethinking and reordering of fundamental relationships and imaginatively mapping possibilities (Alexandra and Riddington 2006; Castree 2014b; Vervoort *et al* 2015). Therefore, an explicit challenge for urban transformations is engaging people in processes that disrupt and challenge notions of possible futures and fixed conceptualisations of what is desirable, feasible or likely (Vervoort *et al* 2015). A range of scenario planning approaches can usefully explore adaptation options (Rickards *et al* 2014; Vervoort *et al* 2015). The benefits of using scenario planning techniques are outlined in the next section.

4.3 Using scenario planning for future making

Scenario practice enables the imagining of futures through creative processes of "world making" that have the potential to reveal much about both the present and ideas of the future (Vervoort *et al* 2015), including the beliefs and mental models that shape our conceptualisation of what is likely, desirable or possible.

Foresighting using scenarios is an established technique used within the discipline of future studies to explore alternative futures (Slaughter 2002; Wright *et al* 2008; Vervoort *et al* 2015). It is a recognised method of investigation, capable of dealing with the non-linearity of complex systems that does not rely simply on extrapolating existing trends (Rickards *et al* 2014; Ison *et al* 2014). It has been used for developing corporate strategies, national science planning (ASS 2012) and climate adaptation (Alexandra 2012; Rickards *et al* 2014) and natural resource management (Soste *et al* 2014).



Scenario planning helps make complex and uncertain futures tractable by using either quantitative modelling or more discursive, symbolic and exploratory approaches for charting futures (Rickards *et al* 2014; Vervoort *et al* 2015). Rickards *et al* (2014) profile the two distinctly different linages and underlying

methods, noting that blends are possible. AAS (2012) provides an example of computer generated quantitative modelling, while Alexandra and Riddington (2002) demonstrate the more symbolic narrative based approach. Emphasising the use of participatory scenarios for empowerment is consistent with Vervoort *et al's* (2015) assertions that we are all world makers, with the explicit challenge of scenario processes being to harness creative powers through engaging people in scenarios that help reorder, recombine, contrast, and challenge our notions of present and future worlds.

Social, economic and ecological systems (socio-ecological systems) are complex and dynamic (Folke *et al* 2002), with trajectories influenced by governance processes and institutions (Ostrom 1990; Dryzek 2012) and by the complex interrelationships between beliefs, values, histories, cultural and policy settings – laws, rules, and social norms – and biogeographic contexts (Dore *et al* 2012; Appaduri 2013). These complex relationships can be usefully revealed through the active engagements in stories or scenarios (Vervoort *et al* 2015).

Some scenario planning methods are being described as a living scenarios in which iterations of scenarios evolve and change through the dynamic exchanges of the participants in forming and reshaping scenarios (AAS 2012; Wright *et al* 2008; de Vries and Petersen 2009; Vervoort *et al* 2015).

Scenarios planning methods are useful given the limitations of the prediction and plan paradigm that influences much of the thinking about the future, particularly under the spectre of changing climates. Rather than simply extrapolating trends or deterministically reducing the future to climate (Hulme 2011) foresighting scenario planning techniques enable alternative futures to be articulated and explored creatively (Slaughter 2002) thus altering both belief and practice (Rickards *et al* 2014; Ison *et al* 2014). As a method of investigation, scenarios are capable of dealing with the non-linearity of complex, coupled social and ecological systems and can be used to emphasise human agency in shaping the future.

Awareness of assumptions that underpin and frame choices used in constructing scenarios is important (Rickards *et al* 2014) and methods used for project governance and stakeholder engagement are also critical because these determine the success of participatory strategies (Soste *et al* 2014). Rickards *et al* (2014) found that effective scenarios combine analysis, imagination and engagement, working as devices that articulate options, and empower thinking, planning and acting. This reinforces Appaduri's (2013) findings that notions of preferable futures are deeply embedded as cultural "facts" and that peoples are adept at articulating these given suitable opportunities.

Combining participatory planning and consultation with foresighting methods assists in enabling steps towards transformative futures. Foresighting can be a useful tool for stakeholder engagement in R&D planning because it allows parties to articulate and make their assumptions about what will help shape preferred futures explicit. Scenarios are devices that assist thinking differently about the future. Use of these kinds of methods can help to identify priorities and see how different aspects can be linked in "future stories". Such stories and the strategies they engender are a form of enactment that can provide the

foundations for transformative change by unleashing ideas about different, better futures and pathways for achieving them. As such, Vervoort *et al* (2015) describe these kinds of processes as world making.

Scenarios are useful for redirecting established mindsets and for identifying trends with Rickards *et al* (2014) identifying that scenario planning supports adaptation to different futures by empowering people to conceive of and prepare for different futures. Unleashing the imagination and creativity is critical to envisaging preferred futures (Alexandra and Riddington 2006) and may contribute to building capacity for transformations (Folke *et al* 2002) because all peoples are engaged in shaping and reshaping the future through their culturally embedded ideals that form the basis of their political actions, preferences and institutional negotiations (Appaduri 2013).

4.4 Building innovative living infrastructure along Canberra's transit corridors

The case for emphasising living (green) infrastructure in the urban renewal projects in Canberra, particularly along the transit corridors, is strong. There is much that we can learn from other cities that have explored and implemented the use of living infrastructure in their development.

There are several types of living infrastructure that are commonly used in urban development:

1. Tree plantings/street trees/urban forests: these are very common and often provide one or more of three essential ecosystem services: (i) amenity and liveability; (ii) shade (adaptation to extreme heat); and (iii) storing carbon (contribution to mitigation of climate change). Trees/forests can also reduce the use of energy for artificial cooling, further contributing to the mitigation of climate change. Furthermore, trees/forests can contribute to better biodiversity outcomes through green corridors and stepping stones that connect nature reserves. This benefit could be important for Canberra to connect its large nature reserves.

2. Water sensitive urban design (WSUD): in general terms, this refers to the management of all components of the hydrological cycle in urban settings in ways that deliver multiple benefits. More specific approaches include retention of natural streams and waterways and their riparian zones, recycling water (e.g., "grey" water), more efficient water use, stormwater recycling via swales and artificial wetlands, and various types of flood mitigation. This is a large and important component of living infrastructure, and is dealt with in more detail in the section on urban water systems below.

3. Green roof-tops and walls: this approach involves growing vegetation of various types on rooftops and on walls. There are many benefits of greening walls and rooftops, such as amenity for building residents, growing food, cooling

and insulating buildings (thus achieving significant reductions on heating/cooling bills), water collection, and as “stepping stones” for biodiversity. There is even a proposal to use roofs for growing blue-green algae as a source for biofuels.

4. Community gardens, edible landscaping (fruit trees, edible perennials): these features can be created on rooftops, alleyways, sideyards, courtyards, formal allotments, raised-bed gardens, and other small areas of dense housing. Havana, Cuba is the classic example of extensive use of urban gardens.

5. Green connectors: these are generally designed to link up other types of living infrastructure and nature reserves to increase the ecosystem services beyond those delivered by each element in isolation. Connectors are often associated with waterways and their association vegetation, but also include strips involving several of the elements described above, often trees/urban forests. Cycleways, walkways, disused railway lines and designated road corridors often provide the “spine” for the connector and are enhanced by the addition of living infrastructure.


Living infrastructure is best implemented not as the individual elements described above but rather as a broad, interconnected green infrastructure network that provides multiple ecosystem services to the urban population. Such networks also help to connect animal and plant populations and their habitats, enhancing biodiversity outcomes which also contribute to ecosystem services. Examples of ecosystem services include absorbing carbon from the atmosphere, absorbing and storing water, reducing flood risks, supporting physical and mental health, reducing risks associated with extreme heat, providing habitats for wildlife, providing insulation for buildings (green roofs and walls).

In addition to the biophysical elements of living infrastructure themselves, there are a number of strategies for successfully implementing living infrastructure initiatives. Two of the most important of these strategies are:

1. Building or enhancing a sense of place: Many urban residents have a strong sense of belonging to their part of the city and its characteristics – their "place" – so involving local residents and communities is essential to help promote, prioritise and design urban green space and living infrastructure development. Approaches that can improve community engagement include involvement as stakeholders in the policy and planning processes, creation of platforms that enable capacity building to understand living infrastructure and the benefits it can bring, and exchange of knowledge and best practices with other cities and regions.

2. Providing financial incentives for the installation of living infrastructure: There are many different approaches to creating such incentives. For example, the City of Vancouver requires that 5 per cent of the value of a development be directed into social infrastructure. Their definition of social includes landscaping, green courtyards, and other types of living infrastructure. A similar approach (National Living Cities Fund) was proposed in 2016 as part of a National Five Point Living Infrastructure Plan for Australia. Also, some cities create their own local currencies (a la carbon credits) to support sustainability initiatives. These 'sustainable development rights' could be related to biodiversity credits,

greenhouse gas reduction credits, salinity reduction credits, affordable housing credits, and so on.

Several case studies provide excellent examples of the implementation of these types of living infrastructure.

<u>Case Study 1</u>: Lisbon, Portugal, has developed an ambitious plan to connect living infrastructure across the city and to connect it with the surrounding region. This has required an integration of separate spatial planning bodies for the city and its region – those for transport, economic development and housing, in addition to living infrastructure. The network is designed to generate ecological connectivity and continuity functions, with the aim of maintaining and improving biodiversity values in the city. It is designed to be integrated into broader municipal and regional planning decisions.

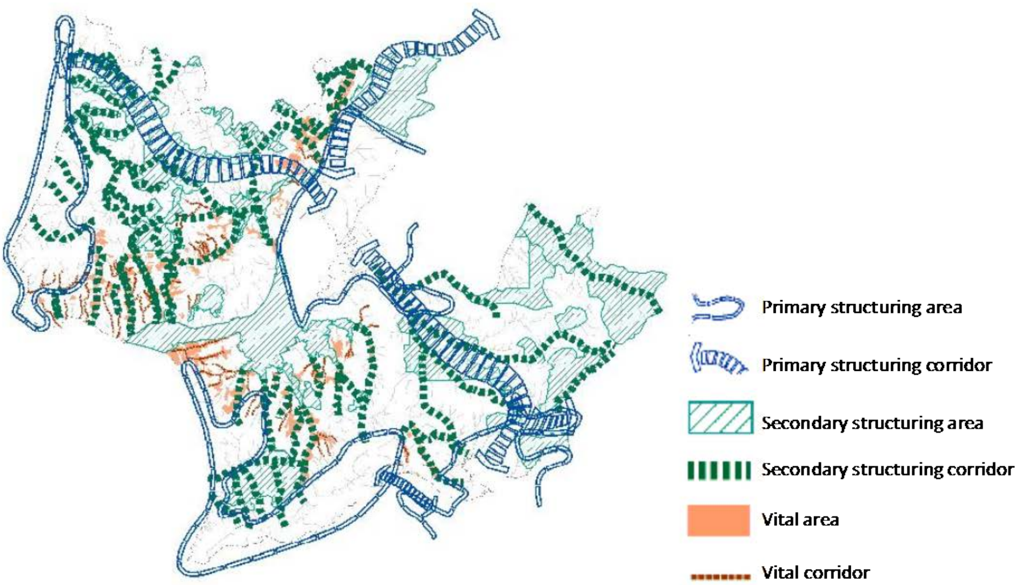


Figure 1: Building an urban ecological network in Lisbon, Portugal, by connecting parks and reserves as well as other areas that provide ecosystem services. Source: Losarcos and Romero (2010).

Elements of Lisbon's living infrastructure network (Figure 1) include: (i) protected areas in the basic nature reserve network; (ii) ecosystem service areas (areas not gazetted as nature reserves but have been identified as being

important for delivering ecosystem services to the community); (iii) natural connectivity features (e.g., streams with their riparian zones); and (iv) new urban green areas created to build the missing connectivity after the other pieces of the network have been identified. The projected benefits of the network are primarily aimed at biodiversity but also deliver a number of other benefits, including recreation and tourism, improved water quality and enhancement of natural heritage and landscapes.

The plan itself consists of a hierarchy of green areas and corridors according to their importance (for biodiversity) and their contribution to value of the overall network. The areas and connectors generally have natural, cultural or landscape values, or a combination of these values.

Case Study 2: Barcelona, Spain, has developed a set of green corridors (strips of urban land covered in vegetation) that help to connect urban green areas within the city and to connect the city with the surrounding environment such as the coastline (Figure 2). Because of its high density, the city's approach has a strong focus on a process called "naturalisation" – filling built-up spaces such as courtyards, roofs and walls with greenery. Benefits include reducing noise, absorbing air pollutants, lowering energy consumption, balancing the water cycle and supporting biodiversity. Most importantly, naturalisation creates a more appealing environment to live in and improves the health of urban citizens.

As for Canberra, Barcelona places a strong emphasis on the city's trees – street trees (Figure 3), trees in parks, shrubs and trees in nature reserves. In the Barcelona case, trees play an important role in filtering harmful substances from the air. Although this is not generally a problem in Canberra, it may well become one along heavily travelled transit corridors.

Figure 2: Depiction of existing green corridors in the eastern area of Barcelona linking nature reserves/urban parks. Source: URBES (2014).

Figure 3: Lines of street trees act as a green corridor through a very dense section of Barcelona. Source: URBES (2014).

Case Study 3: Singapore is now well-known as the greenest city in Asia, and has developed a reputation as a worldwide leader in building living infrastructure. The new ethos for the city is to move from "the garden city" to "the city in a garden". There are a number of prominent elements to Singapore's approach to living infrastructure.

- The Skyrise Greenery Initiative: This initiative provides subsidies for roof and wall greening (Figure 4) as well as for balcony gardens, and the city has made how-to handbooks widely available to residents and developers. Also, the city has built a demonstration area in the Hort Park region showing how to construct green roofs/walls and urban gardens.

Figure 4: Example of a large-scale green roof development in Singapore. Source: Karlenzig (2015).

- A Streetscape Greenery Master Plan: This is a crucial part of the Singapore initiative that focuses on the installation of green infrastructure – street trees, gardens, etc – along many of the city's transit corridors. A highlight

of the master plan is the creation of 'heritage roads' with complete canopy cover and heritage tree plantings along the road.

- Guidelines for water sensitive urban design and construction, green wetlands and drains: One of the primary motivations for this part of Singapore's living infrastructure planning is water security. Being a very densely, populated city–state, Singapore does not have large catchments within its territory so harvesting and recycling the water that falls on the dense areas of the city is essential to increase water security.

- Park Connector Network: This visionary initiative aims to bring together the various elements of Singapore's living infrastructure program by driving green connections across the city via strips of living infrastructure using, for example, a disused railway line. More than 360 km of park connectors will be built by 2020, and a 150 km round-island route is in the pipeline. Connectors include promenades, boardwalks, bridges and rehabilitated drainage routes, with more innovative approaches including tree-top walkways.

- Singapore has also established widespread fruit tree planting and community gardens programs as component of its living infrastructure initiative.

These case studies provide information and inspiration for how Canberra could integrate living infrastructure centrally into its urban renewal planning, starting with the urban renewal taking place along stage 1 of the Canberra Metro system.

Five ideas for an innovative, Canberra-based approach, with a focus on urban renewal along transit corridors:

<u>Design competition</u> – open up a competition for the most innovative, effective designs for living infrastructure along the Gungahlin–Civic light rail corridor at various scales – from individual buildings to precincts to the corridor as a whole.

The challenge is to make Canberra a showcase for building high quality living infrastructure, in keeping with Canberra's reputation as the bush capital with large nature parks, more formal gardens and large expanses of street trees. The design competition would be an excellent way to engage the community, and get their involvement in and support for the roll out of transit corridors with denser built infrastructure than Canberrans are normally accustomed to.

<u>Integrated planning</u> – this is repeatedly cited as critical for effective living infrastructure development, as in the three case studies above. The challenge here is planning at a number of scales, from individual pocket parks and walking corridors between light rail stations/stops and the surrounding areas, to green precincts as a whole (e.g., the mid-town development around the intersection of Northbourne and MacArthur avenues), and to larger-scale connectivity between the transit corridor and the large nature reserves (Black Mountain/O'Connor Ridge and Ainslie–Majura) that bound the inner Canberra segment of the transit corridor. The latter could take the form of cycleways, walkways, streets or smaller parks (existing or new) that could act as connectors. In particular, refurbishment of Haig Park might be a good example of such connectivity.

<u>Blue infrastructure</u> – Sullivans Creek offers a good opportunity to build high-quality blue infrastructure that crosses and then parallels the transit corridor. The ANU segment as well as the recent Lyneham wetlands development offer two examples of what can be done to enhance the quality of the creek. These two need to be linked, and the Lyneham development extended upstream to complete this piece of blue infrastructure.

<u>Challenge to private sector developers</u> – the initial light rail corridor offers an excellent opportunity for the private sector to play a prominent role in creating living infrastructure. The New Acton precinct could serve as a model of how high quality, multi-purpose built infrastructure can benefit from careful planning and a strong emphasis on living infrastructure, including green walls and roofs, pocket parks, green courtyards and shade trees and plantings. Incentives need to

be devised to encourage developers to put a high priority on living infrastructure in their developments.

A climate scorecard -– Initially, this approach could focus on three main metrics: (i) Storing carbon, in which the goal is store more carbon in the landscape after the urban renewal projects are complete than before. This requires an inventory of carbon stocks before and projected carbon stocks after the development, with the roll out of living infrastructure playing a strong role in enhancing carbon stocks. (ii) Living infrastructure can play a crucial role in adapting to extreme heat in urban renewal areas. Shade trees are very important, but living infrastructure also helps to ameliorate extreme heat through the cooling effect of evapotranspiration. This requires an integration of water provision and management (e.g., Water Sensitive Urban Design) with the plant components of living infrastructure. (iii) Managing water (WSUD) must account effectively for a changing climate. Two major challenges must guide development of blue infrastructure in Canberra: the risk of water scarcity given the projection of more prolonged and severe droughts for Canberra, and, on the other hand, the need to plan for flood mitigation given the projection of more intense rainfall events.

5 Urban adaptation and living waters

5.1 Rethinking urban water

Climate change is altering the political and physical geographies of water (Bates *et al* 2008; Xu *et al* 2009; Eriksson *et al* 2009) redefining challenges for water governance (Godden *et al* 2011; Pahl-Wostl 2007; Rijke *et al* 2013). Climate risks and uncertainty are leading to the reformulation of water and natural resources policies (Alexandra 2012; Pittock *et al* 2015; Grafton *et al* 2013, 2014).

In Australia, significant drying in the populous South East of the continent is highly likely (CSIRO 2008, 2010, 2012) and climate change has been defined in law as a major risk to water resources and aquatic ecosystems (Commonwealth 2009, 2012).

With climate change risks and uncertainty different to those deriving from a variable climate, urban water systems need to be reconceived. Adaptive water strategies need different ways of thinking to those that have traditionally dominated water management (Alexandra 2012; Godden *et al* 2011; Pahl-Wostl

2007). Climate change has resulted in the “death of stationarity” undermining the foundations of hydrology, so that past ways of knowing are rendered less reliable guides to the future (Milly *et al* 2008). Furthermore, there are calls to take the concept of ‘waste’ out of wastewater and see it as a resource to be managed in ways generative of value (Grant *et al* 2012).

Australia’s urban water regimes have evolved under a highly variable climate with recurrent, severe, decadal droughts interspersed with episodic floods (Kiem and Verdon-Kidd 2013; Gergis *et al* 2012; Tozer *et al* 2015) but climate change is likely to make extreme events more severe and frequent (CSIRO 2010, 2012). For the Canberra region, more intense storm events and longer, more frequent and more intense droughts are predicted (CSIRO 2010, 2012) with an increase in associated fire risks.

Historic thinking about climate embeds certain expectations of normality. The statistical and cultural construction of ‘normal’ climate relies on elaborate systems of measurement and the statistical manipulation of data to arrive at averages for a given location (Hulme *et al* 2008). Deviations from the average are frequently referred to as ‘anomalies’, implying the abnormality of the non-average conditions. However, in southern Australia, conditions coincidently conforming to the “average” are unusual due to fundamental drivers of the continental climate in the Southern, Indian and Pacific Oceans (Kiem and Verdon-Kidd 2013; CSIRO 2010, 2012). Reconstructions of the climate beyond the instrumental records indicate that recurrent droughts punctuated by floods are typical of the long-term patterns (Gallant and Gergis 2011; Tozer *et al* 2015).

Operating in highly variable climates has posed substantial challenges for securing water supplies in Australia (Larsen *et al* 2014). Australia’s urban areas have had several distinct water planning problems – securing reliable supplies of potable water usually from large dams in their hinterlands and the draining of “waste” water away through sewerage and stormwater systems designed to handle both the long dry periods and the episodic floods.

The water infrastructure and technologies adopted and the way they handle water has a powerful bearing on the kinds of urban stream networks and associated urban aquatic ecosystems that emerge. Urban areas have a range of distinct issues arising from changes in urban hydrology. Impervious surfaces (roofs, roads, pavements, car parks etc) shed water rapidly concentrating it in networks of drains and creeks, posing particular challenges for stream restoration (Walsh *et al* 2005). Runoff from cities and suburbs is also a source of major water quality problems as a result of nutrients, pollution and sediment draining to streams, lakes and rivers.

5.2 Technologies and infrastructure for living water

In urban areas, living infrastructure approaches redirect and reconceive of waste waters, especially stormwater, as a resource, that can be managed to enhance urban amenity with wetlands or urban forests (Grant *et al* 2012; Young 2011). A wide range of viable strategies and technologies exist for redirecting stormwater towards biologically and industrially productive uses (Wong 2006), including through flood outs, ponds, dams, wetlands, water gardens and soaks that can be constructed on both public and private land.

Constructed ponds, urban wetlands and water gardens enhance the diversity, productivity and amenity of urban ecosystems. These systems have been extensively studied in the USA (USEPA 2016), Europe (Shutes 2001; Shutes *et al* 1997) China (Qingan *et al* 2001) and Australia (Wong *et al* 2006) to extent that they can be considered proven technologies. They have been assessed for pollution mitigation (USEPA 2016; Hsieh and Davis 2005) and for promoting urban biodiversity (Gaston *et al* 2005) and flood minimisation and retention (Guo 2001). Ward *et al* (2012) articulates the characteristics of a water sensitive city while Ferguson *et al* (2013b) explore transition pathways. Priestly *et al* (2011) have developed indicators of urban water sustainability and a wide variety of software, modelling and measurement tools for urban water systems have been developed (Wong *et al* 2006; Dotto *et al* 2012; Bach et al 2012; Kenway *et al* 2012; Rauch *et al* 2012).

The US EPA (2016b) outlines strategies for using green infrastructure for both flood mitigation and drought resilience. Beneficial uses of urban stormwater are profiled extensively on the US EPA's website devoted to green infrastructure (US EPA 2016) including extensive technical reports on best practice (Appendix B).

Overall the literature on rethinking water to support sustainability and climate resilience identifies many opportunities and technologies suitable for transforming urban water systems (Elliott and Trowsdale 2007), whilst also emphasising the need for systems approaches that includes appropriate governance processes and institutional structures (Brown *et al* 2011; Rijke *et al* 2013).

5.3 Governance institutions for living water infrastructure

After a comprehensive review, Australia's National Water Commission (NWC 2011) urged Australian Governments to reform urban water to make *"more liveable, sustainable and economically prosperous cities"*.

The CRC for Water Sensitive Cities calls for a radical rethink of urban water systems stating that in *"the context of climate change, resource limitations and other drivers, there is growing international acceptance that conventional technocratic approaches to planning urban water systems are inadequate to deliver the services society requires"* (Ferguson *et al* 2013a). The CRC adopts a 'societal needs' approach to urban 'livability' arguing that water sensitive design includes *"considerations of urban amenity, public health, urban microclimates and heat mitigation, biodiversity and the ecological health of natural environments and receiving waters"* *(CRC* for Water Sensitive Cities 2016).

Cities and their water systems are co-evolved with complex hydrological, social and political dynamics. The social and historical constructions of disciplines like engineering hydrology have had strong influences on the adoption of specific policies, technologies and approaches to water management, contributing to reinforcing established regimes of control (Linton and Budd 2014; Molle *et al* 2009). Therefore, the transformation of urban water systems includes both technological innovation and broader challenges of governance and institutional reform (Rijke 2013; Ferguson 2013). While Godden *et al* (2011) claim that climate change is driving experimentation and innovations in water governance, Brown *et al* (2011) document significant risks of professional and agency

entrapment in the urban water sector where certain established paradigms and approaches continue to dominate. This supports Molle *et al* (2009) warning about the water sector's capacity for rhetorical appropriation of social and environmental critiques whilst retaining its heavy construction orientation and modalities of command and control.

5.4 Living water infrastructure for Canberra

Canberra faces the challenges of adapting to changing rainfall patterns that are predicted to bring more intense rainfall events, with increased risk of flooding, as well as longer and more intense droughts (CSIRO 2010, 2012). Any program of living infrastructure will need to be designed with these prospective changes in mind. Expanding urban stormwater storages and flood retention wetlands can assist in reducing risks and increase urban water reuse. Good practice design aims at minimising the risks associated with changing rainfall regimes whilst generating a range of complementary outcomes or co-benefits, like habitat provision and urban cooling.

The ACT Government is already trialling many water sensitive urban design approaches with its urban lakes and constructed wetlands, swales and enhancements of natural drainage patterns. Canberra can demonstrate leadership through a commitment to the adoption of best practice in new urban developments and an ongoing program of retrofitting in established areas. Sullivan's Creek provides a useful 'school house' of the changing patterns of urban stormwater management over the decades since the 1970s with its concrete silt traps and trash racks through to more recently constructed grassed swales and wetlands. This evolution in engineering was used by for educational purposes on a project focused on building professional capacity in the Indonesian water sector (Alexandra unpublished).

There are many opportunities to combine water sensitive design with urban forestry. Of particular relevance is slowing the rates of discharge of stormwater to streams by increasing infiltration to promote wetland vegetation and/or tree

and plant growth, with resulting habitat creation and carbon sequestration (Bartens *et al* 2008; Escobedo *et al* 2011). Tree growth in most of Australia is moisture limited (Donohue *et al* 2011) and therefore there are strong prospect for creating pockets of enhanced growth in places where runoff is concentrated (Xiao *et al* 1998).

Micro-pockets of urban “floodplain forest” could mimic the more extensive flood plain forests, like the River Oak (*Casurina cunninghamiana*) or Redgum (*Eucalytus camaldulensis*) forests that occur along many Australian rivers (Bren and Gibbs 1986; Briggs and Maher 1983). As productive, biodiverse urban forests these fertile patches (Tongway and Ludwig 1996) concentrate water and nutrients, producing highly productive urban ecosystems with higher rates of carbon sequestration and more effective cooling than surrounding sclerophyll vegetation. The beneficial ecosystem services generated by urban forests is described further in section 7 on living carbon.

6 Reducing hazard and risks

There is much literature on urban climate adaptation focused on quantifying and minimising hazards and risks (Spyratos *et al* 2007; IPCC 2012; Wilbanks and Fernandez 2014; Booth and Charlesworth 2014; Žuvela-Aloise *et al* 2016; Maksimović *et al* 2014), including through multi-level risk governance (Corfee-Morlot 2011). This section outlines some key aspects of risk management significant to Canberra – principally bushfire risk.

6.1 Designing living infrastructure to minimise bushfire risk

Human burning of Australian landscapes has long and proud tradition in Australia (Gammage 2008). Nonetheless there are contradictory and confusing approaches to fire and its place in the landscape, with deep concerns about catastrophic fires and their human impacts.

Canberra's climate conditions and extensive bushland margins increases the risks of bushfires impacting on urban areas. This spatial configuration plus the fire prone nature of South-Eastern Australia make bushfires a significant and

pervasive threat. The seriousness of this threat is emphasised by Canberra's 2003 fires (Bartlett 2012) and the 2009 fires on Melbourne's northern margins with both resulting in significant loss of human lives and property (Cameron *et al* 2009). Whittaker and Mercer (2004) found that divisive politics of blame follows major wild fires and that the claims about the 'naturalness' of bushfire can be used as a way of absolving responsibility for fire prevention.

Peri-urban fires are of particular relevance to Canberra because of their potential catastrophic impacts. Canberra's physical layout amplifies fire risks due to the length and nature of the urban bushland interface. The combination of suburbs surrounded by significant areas of bushland and Pinus radiata plantation produces major fire risks (Bartlett 2012). These risks are further amplified by the large number of "blockies" and "hobby farms" surrounding the ACT in adjoining areas of NSW. These increase the risk of ignition sources on days of extreme fire danger. The risk of significant fires increases due to climate change and increased investment in fire prevention is likely to be called for (Pitman *et al* 2007). The inclusion of land use and planning strategies will be central to fire risk reduction because capacity for wild fire suppression is inevitably limited during extreme conditions.

The literature identifies a number of options for reducing fire risks. Spyratos *et al* (2007) used a simple fire-spread model, informed by housing and vegetation data to demonstrate that the size and impacts of wildfire can be modified by the density and flammability of buildings. This study highlights that knowledge of the location, spatial distribution, density and flammability of "*buildings should be taken into account when assessing fire risk at the wildland-urban interface*" and used to mitigate fire risk.

Gill and Stephens (2009) identify a range of critical issues about managing fire risk on the urban-bushland interface of relevance to Canberra. Dombeck *et al* (2004) call for an integration of technical and social aspect of fire risk reduction across multiple tenures. Bartlett (2102) recommends increasing the size of fire breaks located between pine plantations and suburbs while Agree *et al* (2000)

identify an increasing interest in the use of fuel reduction zones for fire protection with one option being the 'fuelbreak' – areas of land "*manipulated for the common purpose of reducing fuels to reduce the spread of wildland fires, and in forested areas the term is synonymous with 'shaded fuelbreak' as forest canopy is retained on site*". Agree *et al* quote Green's (1977) definition of a fuelbreak as "*a strategically located wide block, or strip, on which a cover of dense, heavy, or flammable vegetation has been permanently changed to one of lower fuel volume or reduced flammability".*

Agree and Skinner (2005) document a range of forest fuel reduction strategies that can be applied at scale. Such strategies incorporate forest management and complementary land use planning options. In terms of living infrastructure fuelbreaks and fuel reduction, zones using bands of deciduous trees on the bushland margins may be useful for slowing fire spread because these trees tend to have lower flammability, reduce wind speed and steam rather than explode when during fires. There appears to be limited literature on using lower flammability or fire retardant tree species in large-scale applications although there are some guidelines for home gardens (Detweiler and Fitzgerald 2006). Gibbons *et al* (2012) undertook an analysis of key variables effecting loss of houses due to wild fires at the urban interface concluding that focusing on fuel reduction close to houses is likely to be more effective than generalised fuel reduction strategies.

BOX Text 1: Ideas about use of fuel breaks and fuel reduction zones

Canberra has extensive suburban areas adjoining bushland and pine plantations that are exposed to significant bushfire risks. These risks manifested with catastrophic consequences in 2003 with tragic loss of lives and over 250 houses destroyed in suburbs adjoining the Mt Stromlo Pine Plantation. "Forty-three per cent of houses in the 125–152m-wide plantation ember zone at the urban interface were destroyed, apparently as a result of heavy ember attack. The width of the existing buffers had little impact on the proportion of houses lost" (Bartlett 2012). The western suburbs of Canberra were established in the 1970s

adjacent to the Stromlo pine plantation with interface treeless buffer widths of between 55m and 82m.

Given the risks and the lessons from this history it is important that Canberra proactively manage for increasing fire intensity and risk predicted under climate change (Pitman *et al* 2007).

One option worth further consideration is the use of strategic fuel breaks which would bring together a range of land use and land management strategies to ensure that fire risks are minimised on the suburban boundary.

These fuel reduction zones could include combinations of strategically located dams, wetlands and swales along drainage lines to increase retained moisture, areas of irrigated lands such as sports fields, market gardens, parklands and forested lands managed to ensure fuel loads are minimised – for example, use of low flammability tree species (such as poplars and oaks), and use of appropriate methods to reduce ground fuels, such as grazing, controlled burning and mowing.

The resulting fire protection and fuel reduction zones could be gazetted as with parks with their primary purpose being as strategic 'fuelbreaks' – areas of land "*manipulated for the common purpose of reducing fuels to reduce the spread of wildland fires, and in forested areas the term is synonymous with 'shaded fuelbreak' as forest canopy retained on site*" (Agree *et al* 2000). Agree *et al* quote Green's (1977) definition of a fuelbreak as "*a strategically located wide block, or strip, on which a cover of dense, heavy, or flammable vegetation has been permanently changed to one of lower fuel volume or reduced flammability*".

Agree and Skinner (2005) developed "*a set of simple principles important to address in fuel reduction treatments: reduction of surface fuels, increasing the height to live crown, decreasing crown density, and retaining large trees of fire-resistant species. Thinning and prescribed fire can be useful tools to achieve these objectives*".

It is easy to visualise a ring of parkland bordering all the existing and planned suburbs which while used for many purposes is specifically functioning to minimise the risk and impacts of bushfires. These fuelbreaks and fuel reduction zones would add a rich dimension to Canberra's urban fringes and assist in limiting the spread and intensity of fires. They could incorporate multiple passive and active uses including for example, sports fields, horse agistment paddocks and riding paths, dedicated mountain biking areas and urban farms.

6.2 Living infrastructure reduces extremes of heat and cold

Other risks of significance to Canberra include heat stress (Žuvela-Aloise *et al* 2016) and more intense storms and flooding (CSIRO 2010, 2012). The latter is addressed in the urban water section above.

Žuvela-Aloise *et al* (2016) simulated urban temperature conditions for Vienna, modelling terrain, land use and climate data and the modelling showed that living infrastructure (green and blue) when applied extensively results in substantive cooling at the city scale. This study demonstrated that the *"best efficiency can be reached by targeted implementation of minor but combined measures such as a decrease in building density of 10 per cent, a decrease in pavement by 20 per cent and an enlargement in green or water spaces by 20 per cent".* Likewise, Li *et al* (2011) found strong correlative evidence for the relationships between urban vegetation and reduction in the urban heat island effect. In contrast, Bowler *et al* (2010) reviewed the evidence of urban cooling derived from vegetation and vegetated spaces: while finding parks and treed areas were cooler, they found inconclusive evidence of a city wide cooling effects. This is in contrast with the findings of Chen *et al* (2006) who used remote sensing to find strong supportive evidence for the cooling effects of vegetation at the scale of emerging mega cities. Other studies emphasised the value of living roofs and reduced hard pavements surfaces (Coutts *et al* 2013) while Shashua-Bar and Hoffman (2000) found that even small pockets of shade trees and other greenery reduce the impacts of extreme heat and urban heat island effects. In

Victoria, a policy briefing on urban heat reduction outlines beneficial strategies for heat reduction including through ponds, street trees and parklands (VCCCAR 2015).

Based on the findings of the literature review, inner Canberra is already receiving significant cooling from its urban vegetation (Li *et al* 2011; Chen *et al* 2006; Oliveira 2011; Žuvela-Aloise *et al* 2016). However, recent heat studies indicate a significant variation between inner Canberra and the newer, less treed suburbs on the urban fringe (Hanna 2015). The impacts of extreme heat and the urban heat island effects can be minimised by:

1. ensuring ongoing programs of urban forestry and maintaining appropriate ratios of open spaces and treed areas to areas with hard surfaces (car parks, roads and buildings)
2. channeling urban run-off to tree areas increasing their evapo-transpiration capacity and cooling impacts (Bartens *et al* 2008; Escobedo *et al* 2011)
3. further development of well-designed water bodies (lakes, ponds and wetlands) because these provide cooling services (Žuvela-Aloise *et al*

2016) along with nutrient striping, water quality, amenity and habitat services

4. using living roofs on suitable buildings and cooler colours on hard surfaces (Coutts *et al* 2013), and
5. integrating living infrastructure and shade into urban precincts.

In summary, the literature is clear about the significant role of living infrastructure on temperature regulation in urban areas, with benefits derived from both reducing heat – and therefore the health and energy use consequences of operating in hot cities – and improving the thermal conditions during cold conditions. This occurs through vegetation reducing wind speed and wind chill, therefore reducing heat loss of buildings, the energy used and the cost of heating. For Canberra reducing the energy consumed in heating residential and commercial buildings is a significant benefit that has both climate and equity dimensions, because poorer residents pay a higher proportion of the income on the costs of heating and cooling.

6.3 Using climate prediction to reduce risks

Australia's wetter and drier phases have different risk and resource profiles. Living infrastructure can be designed and managed to be useful in both the drought and flood phases of the climate cycle. Given that this can now be more accurately predicted with some reliability, this capacity should be used for risk management and operational planning (Kiem and Verdon-Kidd 2013). Flood and drought risks vary significantly across annual and decadal time scales depending on whether Eastern Australia is in its wet or dry phases, with each of these phases dependent on the conditions of the Pacific and Indian Oceans (Kiem and Verdon-Kidd 2013). Ocean conditions provide useful predictive indicators that can be used in seasonal anticipation of different risks – floods, drought and fires – and to dispense with the idea that in any given season the probability of risks is roughly equal. Kiem and Verdon-Kidd (2013) use predictive climate states to estimate flood frequency probabilities, demonstrating that the one in the 100

flood risk probabilities are a mythical average, with limited relevance to planning for actual events. For Eastern Australia they argue that:

> *"The probability of occurrence for an annual maximum flood during a La Niña year is much higher than the probability of occurrence for a flood of the same magnitude in El Niño events…nearly all La Niña events will be associated with an above average annual maximum flood event somewhere in NSW. Also strikingly apparent … is the inadequacy of the traditional 1-in-100 year flood estimate. If the risk of flooding is assumed to be the same from year to year (i.e. the traditional and current assumption) then the chance of flood occurring during La Niña events is severely underestimated."*

The use of seasonal climate prediction can be used to reduce risks and enhance operational planning because for example, the risk of fires is increased in the dry sequences.

7 Trees as living carbon

7.1 Urban forests – the many benefits of urban trees

This section summarises the roles of trees, urban forests and parklands as contributing to the pool of living carbon in cities amongst other benefits.

Australia had several pioneering advocates of urban forestry. PA Yeoman's (1971) book 'The City Forest' is a classic reference that continues to inspire many, including one of Australia's most prominent gardening personalities Costa (Georgiadis 2013). Similarly, John French, a Cambridge trained forester working for CSIRO on termites, was an inspiring advocate for urban forestry frequently presenting on the ABC in the 1970s and 1980s and outlining the benefits of urban forestry in journals (French 1975, 1983).

More recently a revival of interest in urban forestry is demonstrated with strong advocacy from the City of Melbourne and Horticultural Innovations Australia who have produced the urban forest strategy workbook – "How To Grow An Urban Forest – A ten-step guide to help councils save money, time and share practical knowledge" (http://202020vision.com.au/media/41948/urban-forest-strategy-workbook.pdf.

With the global revival of interest in urban forestry there is active re-evaluation of the benefits of urban trees – from the humble street tree through to major urban forests (VCCCAR 2015). Many studies focus on urban trees in terms of ecosystem services, for example, Bolund and Hunhammar (1999) identify seven different types of urban ecosystems that generate ecosystem services, with trees and parklands featuring in four: street trees; lawns/parks; urban forests; cultivated lands; and waterscapes featuring in the others: wetlands; lakes/sea; and streams. The local and direct services identified were – air filtration, micro-climate regulation, noise reduction, rainwater drainage, sewage treatment, and recreational and cultural values. Their study found that ecosystem services generated within urban areas produce positive effects on quality-of-life and are worthy of more active consideration in land use planning. Escobedo *et a*l (2011)

also found that urban forests produce services of pollution reduction and carbon sequestration. Likewise, Jim and Chen (2009) analysed urban forestry in China concluding that *"the major ecosystem services provided by urban forests in China, including microclimatic amelioration (mainly evapotranspiration-cooling effects), carbon dioxide sequestration, oxygen generation, removal of gaseous and particulate pollutants, recreational and amenity".*

Valuation studies also provide evidence of the multiple benefits of urban trees. For example, in the USA MacPherson *et al* (2005) argue that city trees are *"viewed as a best management practice to control stormwater, an urban-heat–island mitigation measure for cleaner air, a CO_2-reduction option to offset emissions, and an alternative to costly new electric power plants. Measuring benefits that accrue from the community forest is the first step to altering forest structure in ways that will enhance future benefits."* In their study on Municipal Forest Benefits and Costs in Five US Cities (PDF) they describe the structure, function, and value of street and park tree populations in five cities (Fort Collins, Colorado; Cheyenne, Wyoming; Bismarck, North Dakota; Berkeley, California; and Glendale, Arizona). Their study found that although "*these cities spent $13 to $65 annually per tree, benefits ranged from $31 to $89 per tree*" and that for every dollar invested in management, benefits returned annually ranged from $1.37 to $3.09.

In "Planting the living city: Best practices in planning green infrastructure" Young (2011) provides a guide to large-scale urban forestry – as a form of green infrastructure, arguing it deserves institutionalised support like other forms of urban infrastructure. Based on studies of urban forestry in eight US cities, Young (2011) identified that large scale tree planting initiatives employed a range of strategies from highly institutionalised data driven approaches to dispersed community led projects. He concluded that institutionalised support with *"diverse funding structures and robust, agency-level commitment to maintaining and expanding urban forests were considered most effective in advancing urban forestry".*

While urban trees and forests are recognised as having multiple benefits (Novak 2006; Konijnendijk 2003) the specific benefits of urban forests are usually defined as:

1. micro climate regulations, including reducing urban heat island effects and cooling cities (Bolund and Hunhammar 1999; McPherson 1997; Gill *et al* 2007; Chen *et al* 2006)
2. reducing air pollutants (McPherson 1997; Lui 2012)
3. increasing carbon sequestration (Nowak and Crane 2002; Lui 2012)
4. providing amenity to urban residents (Price 2003, Standish *et al* 2009)
5. timber, biomass and bioenergy production (MacFarlane 2009)
6. managing water and waterways (Walsh *et al* 2005)
7. increasing biodiversity corridors and habitats (Alvery 2006; Standish *et al* 2009; Andersson *et al* 2014)
8. community empowerment and social benefits (Driver *et al* 1980)
9. increasing property values (Tyrväinen 1997), and
10. educational, recreational and well-being benefits due to urban amenity and nature based recreation (Tyrväinen *et al* 2005; Jim and Chen 2009; Andersson *et al* 2014).

7.2 Enhancing and quantifying living carbon in Canberra

Canberra's urban tree planting programs "*began in the 1920s and today the urban forest on public lands contains 400,000 trees from over 200 species in streets and parklands"* (Banks and Brack 2003).

Canberra is fortunate in having a detailed model and inventory of its urban trees – the Decision Information System to support the Management of Urban Trees (DISMUT) based on a census of trees in the 1990s, coupled with health, growth and yield models (Brack 2006). It is estimated that Canberra's planted trees "have a combined energy reduction, pollution mitigation and carbon sequestration value of US$20–67 million during the period 2008–2012" (Brack 2002).

This number appears broadly consistent with the literature. MacPherson *et al* (1994) calculated that "*during 1991, trees in the Chicago area removed an estimated 6,145 tons of air pollutants, providing air cleansing valued at $9.2 million dollars…sequester approximately 155,000 tons of carbon per year, and provide residential heating and cooling energy savings that, in turn, reduce carbon emissions from power plants by about 12,600 tons annually. Shade, lower summer air temperatures, and a reduction in windspeed associated with increasing tree cover by 10 percent can lower total heating and cooling energy use by 5 to 10 percent annually*".

The same beneficial effects of urban forests are likely to accrue to Canberra residents, where both heating and cooling costs are significant. In these ways Canberra's urban forests are delivering energy savings and thus reducing carbon emissions and are sequestering carbon.

With continued plantings based on good design, new and more extensive urban forests will sequester and store more carbon than Canberra's extant urban forests. There are various methodologies for measuring the amount of carbon

stored in living infrastructure, including methods to estimate the ultimate amount of carbon stored when the tree reaches maturity (Myeong *et al* 2007; Nowak and Crane 2002). However, given that the Canberra has a detailed purpose-built model based on the tree census it seems that the most useful and cost effective method for estimating the greenhouse gas emission reduction is through continuing to support the use of this model. Similarly, because it is based on actual censuses of trees, it will be relatively simple to measure, estimate or model increases in biomass and carbon sequestration against the baselines of the trees already in the model.

While there has been some long standing scholarly interest in urban forestry (for example, French 1975, 1983; MacPherson *et al* 1994) the literature review demonstrates a revival in international interest in urban forestry. This revival is due to an increasing focus on climate-friendly and adaptive cities. Canberra is well-placed to capitalise on this interest. The ACT Government has a significant opportunity to cement Canberra's place as a global leader in urban forestry. It can build on its historical commitment to urban forestry through sponsoring engagement, education, scholarship and tourism. These kinds of initiatives could

build on the historical plantings, including the street trees and parks, the national arboretum, the botanic gardens and the Lindsay Prior Tree Walk at the Australian National University (ANU brochure undated).

7.3 Living carbon and enhancing biodiversity

Global efforts to develop more systematic approaches to conservation planning have historically focused on identifying priorities for conservation and protection within the formal conservation estate based on nature reserves (see, for example, Watson *et al* 2011; Wilson *et al* 2006). Increasingly there are calls for greater attention to off-reserve conservation including through urban and near-urban conservation and restoration strategies (Chapin *et al* 2009; Standish *et al* 2011; Andersson *et al* 2014). Urban greening contributes to regional scale biodiversity conservation through conserving or restoring habitats and ensuring habitat linkages and corridors. Cities and their influence are one of the dominant factors influencing the survival of many species (Standish *et al* 2009). There is an increasing focus on urban re-wilding strategies aiming to enhance biodiversity (Navarro and Pereira 2012) with Rudd *et al* (2002) identifying the need for reconceiving of connectivity in and through urban areas. Goddard *et al* (2010) argue that urban biodiversity conservation strategies need to be scaled up from gardens, while Andersson *et al* (2014) recommend more focus on urban contributions to meso-scale networks of habitats.

The ecological restoration and re-wilding in or close to cities is an emerging global movement (Diemer *et al* 2003; Jepson 2016). The biodiverse cities movement is sometimes referred to as the Biophilic cities movement (Beatley 2011; Ignatieva and Ahrné 2013). Biodiversity strategies suited to the specific context and historical evolution of cities are being developed (Morimoto 2011) along with methods for better quantification of the benefits of urban biodiversity (Ziter 2016). For example, Nelson *et al* (2009) have developed a spatially explicit modelling tool – Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) – to predict changes in ecosystem services and biodiversity conservation.

Recognising the global biodiversity conservation imperative, there is a call for the application of ecological theory in the development of applied vegetation planting strategies (Hunter 2011). Biodiversity conservation strategies involve restoration, conservation and the creation of novel ecosystems (Schaefer 2009; Standish *et al* 2009). Lisle (2010) draws on Low (2002) to argue for urban ecosystems forming novel ecosystems – a new nature – that deserve to be taken seriously as contributing to wider conservation goals. Standish *et al* (2013) identify options for urban ecological restoration including:

1. conserving and restoring 'natural' areas at the fringes of cities
2. restoring remnants within city areas, and
3. managing novel ecosystems including gardens.

A study in Canberra found that large trees play key roles as keystone structures in urban landscapes (Stagnoll *et al* 2012). Their study found that "*as trees became larger in size, their positive effect on bird diversity increased. Large urban trees are therefore keystone structures that provide crucial habitat resources for wildlife".* They call for "*evidence-based tree preservation policies that recognize biodiversity values"*, and the active protection and planning for large trees as keystone structures in the landscape.

Urban ecologies should not be thought of as only being remnants of former or pre-existing ecosystems that occurred before a city or suburbs engulfed the countryside. Cities are generating novel ecosystems driven by changes in fundamental processes of nutrient, material, genetic energy and water flows (Schaefer 2009), enhanced by people and their processes, like forming garden plots and playing fields that contribute to meso-scale ecosystem processes (Standish *et al* 2013; Andersson *et al* 2014).

In summary, while many cities are aiming to enhance biodiversity conservation, achieving biodiversity conservation goals requires the application of ecological theory in targeted and applied strategies of adaptive management.

8. Enhancing capacity for living infrastructure planning decisions

8.1 Integrated valuations of living infrastructure

The literature on living infrastructure emphasises the need for integrated approaches to planning. Well-designed, innovative living infrastructure represents a significant opportunity as part of the urban renewal process.

Detailed cost benefit analysis is required to develop the business cases for specific living infrastructure initiatives. The literature emphasises that many of the most important benefits of good living infrastructure need to be assessed in terms of community wellbeing and the economic benefits arising from the vibrancy of a 'liveable' city. However, attempts to monetise benefits can often weaken the case for living infrastructure, especially if there is a tendency to focus on narrow costs at the expense of broader benefits for individuals, the community and the environment. Use of guiding principles may be more effective than detailed valuation studies given the intrinsic uncertainty about ecological processes and valuation metrics. The British planning ministry has adopted a clear set of planning principles for living infrastructure stating that "*Local planning authorities should: set out a strategic approach in their Local Plans, planning positively for the creation, protection, enhancement and management of networks of biodiversity and green infrastructure*" (Department of Communities and Local Government 2012 p26).

8.2 Ecosystem services and valuation studies

Ecosystems generate a range of valuable goods and services (ecosystem services) but their long-term capacity to do so is at risk (Millennium Ecosystem 2003). Investment in science, planning and management is called for with many scholars calling for more accurate valuation studies.

The economic value of ecosystem services has been estimated by numerous studies. Costanza *et al* (1997) estimated their value at between $16 and $54 trillion or between one and 3 times annual global gross national product (GNP).

Other studies estimate their value in terms of local and regional impacts (Jim and Chen 2009), quality of life (Bolund and Hunhammar 1999; Nelson *et al* 2009; Gómez-Baggethun and Barton 2013) and in terms of poverty alleviation and provision of livelihood strategies (ME 2003).

Ecosystem valuation studies have been promoted as a means of supporting informed policy decisions (ME 2003). However, the literature on valuation of biodiversity and ecosystem services is increasingly divided. While many authors are calling for better valuation studies as the basis for better decisions (for example, Nelson *et al* 2009), others argue that the ecosystems services approach embeds neoliberal conceptualisations about the environment and its value through the use of market metaphors (Coffey 2016), which entrench commodification and calculative reasoning. The financialisation of nature (Sullivan 2013) and the enthusiasm for neoliberal business modalities is indicated by the way that ecological systems, like rivers and wetlands, are defined as "assets" including in legislation (Commonwealth of Australia 2009) with benefits they generate for humans defined as ecological services (Robertson 2007; De Groot 2012). This economic calculation(ism) or rationalism finds expression in thousands of elaborate, ecosystem services valuation studies (Robertson 2007; De Groot 2012) whose rationale may be the doubtful premise that more accurate ecosystem valuations will lead to better environmental policy decisions (Dempsey and Roberson 2012). Sullivan (2013) suggests that this blizzard of calculation is blinding us to the extreme financialisation of nature where neoliberal business modalities – like environmental markets – are promoted as the solutions and where the wider and deeper roles of government as protectors of the public's long-term interests are subsumed into marketised ideologies (Coffey 2016; Coffey and Marston 2013).

After two decades of ecosystem services valuation studies, the frequently claimed promise that ecosystem valuations lead to better policy decisions has been critically examined (Laurans and Mermet 2014). Explicitly, considering the modes of decision-making processes used in policy processes, Laurans and Mermet reviewed over 313 papers on ecosystem services valuation studies and

their utilisation. They found that belief in the “rational decision” mode constrained the usefulness and applicability of ecosystem services valuations and that more focus on understanding of factors and rationales of how policy decisions are made is needed.

Numerous studies provide conclusive evidence of the high value of ecosystem services, particularly in urban areas. A critical issue for supporting better policy and planning decisions is being able to clearly quantify the human health, social and ecosystem service benefits arising from specific living infrastructure options under consideration. The introduction of guiding design principles that focus on achieving outcomes may be more effective than investing in more detailed valuation studies. However, given the need for policy or regulatory impact statements, detailed cost benefit analysis should be undertaken to support consideration of various policy options (including doing nothing) and to ensure that the recommended policy options are able to be justified in terms of benefits to the community. Despite the intrinsic uncertainty about ecological processes and the fuzziness of some valuation methods and metrics, it is possible to conduct high quality cost benefit analysis when specific policy options are being considered. While this review has identified extensive evidence of the social, economic and environmental benefits of living infrastructure, it is both premature and beyond the scope of this review to undertake detailed valuation studies. Such studies need to be conducted when specific policy or regulatory options are actively being investigated and considered for adoption by governments.

9. Conclusions

Living infrastructure comprises the biological and ecological elements of urban systems that deliver multiple functional benefits to cities. The literature outlined above offers an insight into the global "living cities" movement and the multiple benefits that can be derived from living infrastructure. As part of the wider challenges of transforming cities to meet contemporary needs, programs of living infrastructure provide opportunities to enhance both the physical and social fabric of cities. The literature reviewed strongly supports the adoption of living infrastructure as part of a strategic platform for making more liveable, climate responsive cities. It is clear from the literature that high quality urban planning design offers significant opportunities for our rapidly urbanising planet to meet the pressing imperatives of the 21st Century.

Living infrastructure is part of the new functioning of modern cities, providing renewed interest in the ways in which city parks, urban forests and remodelled waterways can contribute to the revitalisation of urban areas whilst also

contributing to meeting global environmental challenges like climate mitigation and biodiversity conservation.

There are likely to be substantial costs and consequences of cities not adopting active programs of living infrastructure. These costs will be distributed across both the public and private sectors, and will include higher heating and cooling cost, poorer water quality and deleterious health impacts from increase urban heat impacts.

The literature provides strong evidence of the multiple social and economic benefits of living infrastructure including through enhancing equity and access to satisfactory and satisfying lifestyles in cities. The emerging city of the 21st century is based on new visions and new imaginings of the city as nature and the nature of the city. These visions are reinterpreting the possible and the desirable, redefining the kinds of cities that will become attractive destinations for visitors and locales for the enjoyment of urban living. Actively transformed cities are likely to become beacons for commercial and lifestyle investments. Others are likely to be left behind. In this way living infrastructure is much more than an "environmental program" and therefore the full range of these social and economic benefits need to be included in cost benefit analysis of urban policies.

Cities are engaged in a reputational race, in terms of attracting population, investment, employment and tourism. Strengths in innovation, research and education offer a compelling case for Canberra's future, and this can be complemented with bold commitments to making Canberra a great example of a living city. Living infrastructure provides multiple opportunities to give tangible expression to Canberra's aspirations for high quality urban planning, effective decarbonising and leading cultural innovation strategies. Canberra has a unique opportunity to redefine its future vision, so as to become a leader within the global cities movement. The vision includes the ACT's commitment to 100 per cent renewals and its commitment to adopt living infrastructure that builds on its unique heritage of urban planning with its parklands and urban forests. Adoption of an ambitious program of living infrastructure would

establish Canberra as a leader in Australia. Such an option clearly needs more detailed planning and further analysis.

Through reviewing the international literature this paper has sketched out some of beneficial potential of adopting policies that would enable living infrastructure to enhance the city. With a modicum of imagination it is possible to envisage a transformed city: one that integrates the best aspects of contemporary urban design and planning with Canberra's legacy in order to build a capital city boldly suited to the emerging challenges of this century. It would be fitting for Australia's most planned city to integrate its planning legacy with its capabilities to shift fundamentally towards becoming a world-class example of a climate responsive, living or biophilic city that provides healthy, high quality lifestyles to its inhabitants.

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Appendix A – US EPA references re stormwater

Stormwater management objectives have shifted from controlling peak flows to mitigating impacts on water quality and ecosystems. Research on how well stormwater controls reduce pollutant concentrations and loads has generated vast quantities of data. Research organisations have developed databases and summary reports to help decision-makers interpret the data, these include:

International Stormwater Best Management Practices (BMP) Database —This database summarises findings of more than 400 BMP studies. You can perform custom queries or download technical papers that summarize performance results. The database includes information on several green infrastructure controls.

National Pollutant Removal Performance Database, Version 3 (PDF)(10 pp, 1.2 MB, About PDF)—This technical brief by the Center for Watershed Protection summarises the results of the more than 150 performance studies that are included in the database. It includes statistical and graphical data on removal rates for several types of green infrastructure controls.

Runoff Reduction Method Technical Memo - Appendix F: BMP Research Summary Tables (PDF)(85 pp, 401 K, About PDF) —This technical memo by the Center for Watershed Protection presents the results of more than 100 papers in tabular form. Water quality and quantity data are presented for green infrastructure and conventional controls.

Green Infrastructure for Stormwater Control: Gauging Its Effectiveness with Community Partners (PDF) (58 pp, 433 K, About PDF) —This report summarises results to date from research conducted by the U.S. EPA's Office of Research and Development (ORD) into the performance of several green infrastructure practices. Scientists with ORD's National Exposure Research Laboratory/Water Supply and Water Resources Division worked with communities in eight EPA regions to evaluate impacts such as water quality changes, hydrologic response and soil infiltration.

Illinois Green Infrastructure Study (PDF)(126 pp, 1.9 MB, About PDF) —This report summarises pollutant removal and volume reduction results of more than 50 peer-reviewed journal articles. It includes reductions for several green infrastructure practices in:

- total nitrogen
- total suspended solids

- runoff volume, and
- peak flow.

University of New Hampshire Stormwater Center (UNHSC): 2009 Biannual Report (PDF)(36 pp, 225 K, About PDF) —UNHSC operates a field research facility that hosts three classes of stormwater treatment systems: conventional systems, LID systems, and manufactured devices. This report summarises the results of four years of monitoring at the research facility. It provides:

- performance summaries for 17 stormwater treatment practices; and
- detailed cost and performance data for nine stormwater treatment practices.