LITERATURE REVIEW

Green roofs and walls: A mandatory or voluntary approach for Australia?

Green Cities: Expanding the living architecture industry in Australia (GC 15001)

Prepared by University of Technology Sydney
on behalf of Horticulture Innovation Australia

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Cover image: Green wall on One Central Park, Chippendale (P. Osmond, n.d.)

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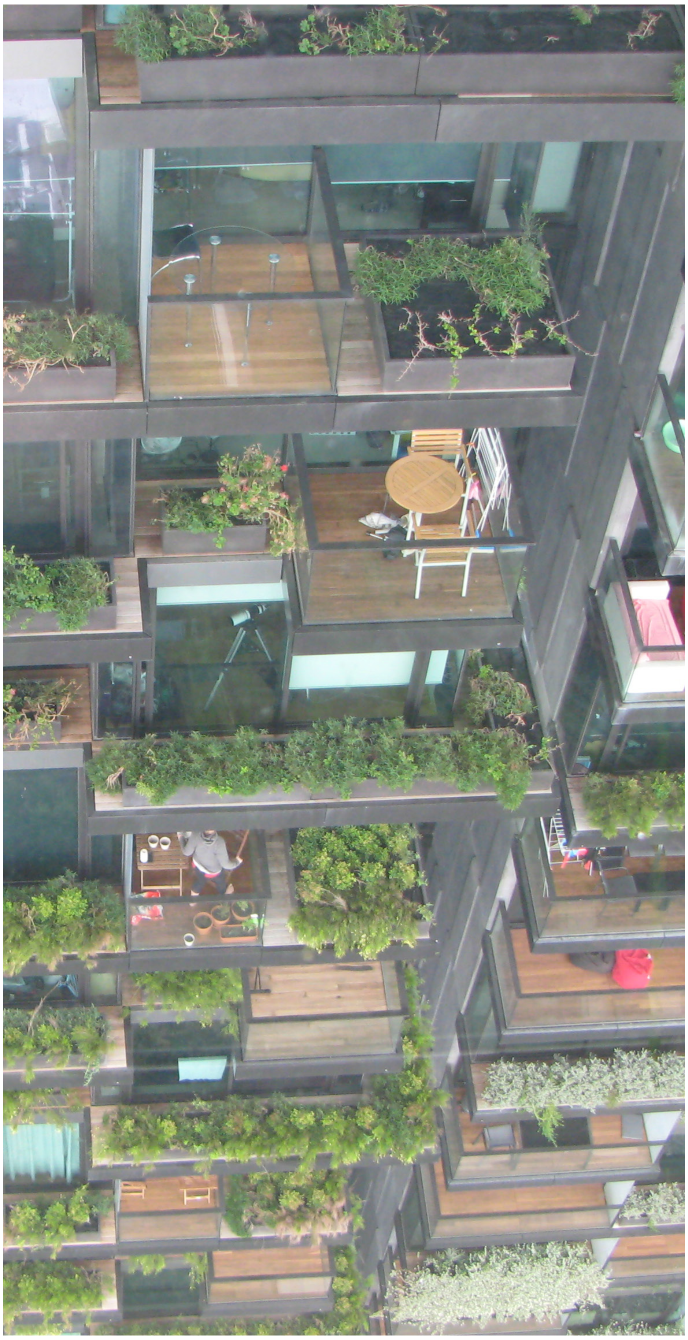


Vertical greening on One Central Park, Chippendale (Source: P. Osmond, n.d.)

EXECUTIVE SUMMARY

This study used a desk-top review of secondary sources to determine the drivers and barriers to the establishment of the living architecture. The review also covered the concept of resilience and resilient cities as there is a strong case for increasing living architecture to mitigate some of the acute and chronic resilience issues. The next stage of the review explored international policy approaches in key cities and then examined Australian State policy. A critical review of factors affecting adoption of mandatory and/or voluntary approaches to green roofs and walls was undertaken, before finishing with a review of the component of, and arguments for and against, the business case for green roofs and walls.

The study concludes there are numerous drivers for the establishment of a living architecture (green roofs, walls and facades) in our cities. As populations grow and cities become bigger, there are corresponding increases in greenhouse gas emissions, air pollution, impervious surfaces urban temperatures as well as loss of tree canopy cover and land for food production. Living architecture can mitigate the negative aspects of these issues. As such green roofs, walls and facades have multiple social, economic, ecological, environmental and health benefits.

Barriers exist and are social, economic, technological and environmental. Costs are a significant barrier, as well as lack of experience in the industry, especially in terms of construction and management. Construction industry and built environment professional capacity for green-roofs is in a developing phase and not fully ready to implement on a wider scale in buildings, precincts, and city scales. Further training and skill development is needed. There is significant potential to retrofit existing buildings, feasibility being determined partly by the structural capacity of the buildings to sustain the additional loads and; this needs to be more fully understood by stakeholders. There is also a lack of appropriate policy and regulations to integrate living architecture practices at the design phase of new buildings and also to retrofit buildings.

Resilience and resilient cities is a concept that will increase in importance. Action at building level is vital and filters up to city, regional and national scales. For example, retrofit of all structurally adequate roofs and walls in Sydney and Melbourne would lead to mitigation of the urban heat island, which impacts on health and livability. Similarly, improvement in storm-water attenuation as a result of mass green roof and wall retrofit decreases the impacts of flash flooding. We looked at case study cities to identify resilience issues and approaches to green roof and walls. Resilience issues in Sydney, Melbourne, Toronto, Singapore, London and Rotterdam are similar and can be mitigated through living architecture. Two resilience issues, heatwave and rainfall flooding, can be alleviated through green roofs and walls.

The review of international policy in Singapore, London, Stockholm, Toronto and Rotterdam demonstrated various approaches taken by policy makers, and a mix of mandatory and voluntary policy mechanisms increase installation of green roofs and walls. The drivers differ, though most are related to issues of increasing resilience and livability. The approaches adopted in these cities are expanded and critiqued in the Case Study report accompanying this report.

No consistent policy approach to green roofs and walls was found in Australian states. No states have a policy for green roofs and green walls, however the City of Sydney and City of Melbourne councils have created policies for each of their LGAs. NSW, Victoria, South Australia and Western Australia have varying numbers of documents, including guidelines and policies, which refer to green roofs and walls. Overall there is a lack of policy to promote living architecture in Australia.

Mandatory or voluntary approaches are key policy mechanisms for increasing green roofs and walls. Four types of policy instruments can be used: information and advocacy; incentives; government demonstration and provision, and regulation. Mandatory approaches fall into the regulation category, while voluntary approaches can be information and advocacy, incentives, or government demonstration and provision. International case studies demonstrate a range of approaches, although our research reveals that there are more voluntary approaches in place than mandatory.

Cost Benefit Analyses undertaken in the US indicated a viable case for large-scale retrofit of green roofs. Increases in residential property value with more green infrastructure in Canada of between 6 and 15% is recorded, and it is recommended a study is undertaken to model the percentage of uplift in value in various Australian cities and suburbs. Furthermore at city scale, modelling in Toronto, Canada showed the UHI could be attenuated by 0.5°C to 2°C through green roof retrofit. If green walls and living walls are added to this calculation, reductions would be greater. Liveability of both Melbourne and Sydney will be affected by predicted temperature increases and we need empirical data for both cities.

The questions that remain unanswered in Australia are; how much green infrastructure do we need to retrofit to achieve resilience? What is the cost benefit analysis for this? And what does the business case look like? Finally, is this more likely to be delivered through a market lead approach, a mandatory approach, or a hybrid of the two approaches? The final report presents different scenarios and modelling to demonstrate the case for mandatory or voluntary approaches and their respective strengths and weaknesses in Australia.

Green roof on One40William, Perth (source: Deep Green Landscaping, 2015)

1. Introduction

This literature review has been prepared by the University of Technology Sydney (UTS) for Horticulture Innovation Australia (Hort Innovation), as part of the research project 'Green Cities: Expanding the living architecture industry in Australia' (GC15001). This research was commissioned by HIA to analyse policy internationally and nationally to ascertain whether, and how far, mandatory and/or voluntary approaches to increase green roofs and green walls, have succeeded, and to provide recommendations for the Australian context.

Green infrastructure offers significant, wide-ranging benefits across economic, social and environmental aspects. As part of green infrastructure, green roofs and walls contribute to these benefits, particularly in dense urban areas. Green roofs improve air quality, provide space for social interaction and relaxation, help manage urban stormwater, reduce the urban heat island effect, provide space for urban food production and improve urban biodiversity. This range of economic, social and environmental benefits has led to the uptake of green roofs and green walls nationally and internationally.

As Australia's population grows, our towns and cities will continue to expand and become more dense, leaving less space for open green space and vegetation. Increasing urbanisation will have significant effects on the natural environment and the health and well-being of human and non-human populations. Green roofs and green walls can help mitigate some of these impacts.

This literature review summarises the key literature about green roofs and green walls. We start with a review of the drivers and barriers for the establishment of a living architecture. This is followed by a discussion of resilience and resilient cities, with reference to issues relating to Sydney, Melbourne, Singapore, London and Rotterdam. We then summarise international policy approaches in Singapore, London, Stockholm, Toronto and Rotterdam and state policy in Australia. These international cities have been selected for their innovative and proactive approaches to green walls and roofs. This is followed by a discussion of mandatory or voluntary approaches to green roofs and green walls. We finish with a review of approaches to creating a business case for green roofs and walls.

We conducted this research through a desktop review of literature, including academic and 'grey' literature (such as government reports, newspaper articles etc). We reviewed a wide range of sources such as academic journal articles, books, industry publications, government policies and guidelines and websites. This literature review represents key findings which will inform the next stage of the project, the research report.

2. Drivers and barriers for the establishment of a living architecture

Drivers for Living Architecture

Cities are becoming more dense and compact as two-thirds of the world population is likely to live in urban areas by 2030 (Population Reference Bureau, 2011). Rising greenhouse gas emissions, increase in air pollution, loss of land for food production due to rapid urbanisation, decreasing tree canopy cover, urban heat island effects, greater imperviousness and building high-density cities to accommodate ever-expanding population are some of the critical challenges faced by many of the world cities (UN-Habitat. 2011; 100 Resilient Cities 2016). Australian cities also experience similar issues. The Australian Climate Change Science Programme projections for Australian cities predict increased average temperature with more extreme heat events, increase in rainfall, drought, fire weather and warmer oceans and sea level rise at a high confidence level (CSIRO and Bureau of Meteorology 2016). Sydney, Melbourne, and Adelaide are already getting warmer up to 4°C when compared to surrounding areas and summer heat in outdoor public spaces in Sydney is increasing beyond human's thermal comfort (Sharfi and Lehmann 2015). Increased heat wave events in Australian cities could lead to higher heat related mortality rate. The contributing factors to urban heat island effects or heat stress in cities include urban landscape composition (e.g. urban greenery ratio), urban geometry, surface cover and materials and anthropogenic consumption and related emissions (Oke 2006 as quoted in Sharfi and Lehmann 2015). Water flow in streams supplying water to Melbourne is likely to decline by 7 to 20 percent by 2050, compared to 1990 averages due to drought conditions (UN-Habitat. 2011). Adelaide, Canberra, Perth, Brisbane, and Sydney would also face drought and water shortage problems (UN-Habitat. 2011). Living architecture is viewed as 'a powerful inspirational model' for achieving curative environmental solutions that can restore and enhance amenity, quality of lived experience of people, wellbeing, and productivity (Peck 2012). It is an important pathway to build resilience in cities and communities to deal with the climate change challenges.

Imagining high-density cities integrated with nature is becoming common as pioneering green cities have become exemplars of collective and positive experiences. An important emerging driver for living architecture is people's changing ideas of a city (Klinkenborg 2009) and how a city and its components should be designed and planned as places of social and human-nature interactions. Re-imagining the structures and appearances of current and future cities are going through an innovative phase as the cities are no more thought as an 'antithesis of nature' (Klinkenborg 2009). Through these transformative and regenerative processes, the cities are evolving as naturalised or biophilic human habitats where nature manifests itself in newly urbanised forms such as green roofs, walls, and facades.

People are starting to comprehend the immense value of incorporating green infrastructure or living architectural practices within built environments. Bringing back lost nature in the cities recreates the ground space utilising unused roof and wall spaces of buildings. Practical applications of these practices generate improved thermal performance and sound insulation of buildings, better storm water management, and air quality, increased property prices, the creation of useful places for social interactions and community engagement, cooler cities, and reduction in energy consumption and greenhouse gas emissions. Aesthetic qualities of cities and urban development projects are improved enhancing urban design characteristics of cities. Green roofs also contribute to urban ecology or biodiversity protection and urban food production at commercial scales as rooftop urban farms. Two extensive green roofs in the inner city Berlin covering 650 square metres supported 110 species over a time frame of twenty years (1985-2005) (Köhler 2006). Brooklyn Grange Rooftop Farm in New York includes two rooftop organic vegetable farms with a land area of one hectare and produces over 22,680 kilograms of food annually (Miller 2014). Urban farms open up opportunities for new job creation and local economic development. A perception study conducted in City of Sydney (2017) on green roofs and walls before developing Green Roofs and Walls Strategy for the city. Green Roofs and Walls Strategy for the City of Sydney was adopted in April 2014. This study indicates that associated social amenity values are a primary driver for the acceptance of accessible green roofs installation in buildings (City of Sydney 2017). A higher level of community awareness on green roof and walls was established through this research (City of Sydney 2017).

Increasing numbers of media articles on the green roof topics play important roles in creating public awareness. For example, a Sydney Morning Herald article published in 2008 reported findings that green roofs could lower summer temperature of roofs ranging from 75°C to 120°C to mid to high 30°C in Australian conditions. Technological capacity is also a guiding factor to implement green roofs walls and facades.

Living architecture such as green roofs are multifunctional green infrastructure (Dixon and Wilkinson 2016) and have multiple social, economic, ecological, environmental, and public health benefits. Hopkins and Goodwin (2011) categorised these benefits into two types: public benefits, shared at wider community and government levels and private benefits, received by building owners and occupants. These public and private benefits provide meaningful economic returns. These benefits are the key drivers and central to the uptake of living architecture practices (Hopkins and Goodwin 2011) at various urban spatial scales. Appropriate policy, initiatives, and incentives of federal, state and local governments and key national priorities have significant influences on the processes and guide the progress in implementing green roofs, green walls, and façades at local and city scales. The drivers would also vary with the implementation of green roofs, walls, and facades in different land use zones such as residential, commercial and industrial (City of Sydney 2017) and various locations and at different densities with the city.

With regards to green roofs whether new installation or retrofit stakeholders may make their decision based on one or more the following reasons;

1. Thermal performance – improve insulation and reduce energy consumption
2. Urban Heat Island
3. Storm-water – attenuation of pluvial flooding
4. Biodiversity enhancement
5. Conservation of endangered flora and fauna
6. Urban food production
7. Provision of social space (Wilkinson & Dixon, 2016).

The majority of stakeholders will be concerned primarily with

88 Angel Street, Newtown (source: O. Steele, 2016) the building level rather than the city level. In table 1 the primary and secondary benefits are identified for each type of green roof, similar primary and co-benefits will accrue for green walls and facades to greater or lesser degrees.

More specific research on Australian cities is essential to determine the existing drivers that could continue to influence and new drivers that could arise over the time to impact the green roofs, walls and facades uptake.

Barriers to living architecture

There are significant challenges, barriers, and issues associated with the establishment of living architecture practices (green roofs, walls, and facades) in current and future cities. Retrofitting existing buildings is important as estimates suggest 87% of all buildings we will have in 2050 have been already built. Potential to retrofit existing buildings are determined by the ability of the buildings to sustain structural loads of green roofs (Feitosa and Wilkinson 2016; GSA 2011). Intensive green roofs require supporting heavier weights of deeper soil than the extensive green roofs on the buildings (Downton 2013). In addition the technological capacity and reliability to install green roofs on buildings without the possibilities of leakages and structural damage is an issue of huge importance (GSA 2011). In spite of technological advancements, the reliability of green roof systems and associated risks of leaks are obstacles

Table 1 Green roof type primary and co benefits

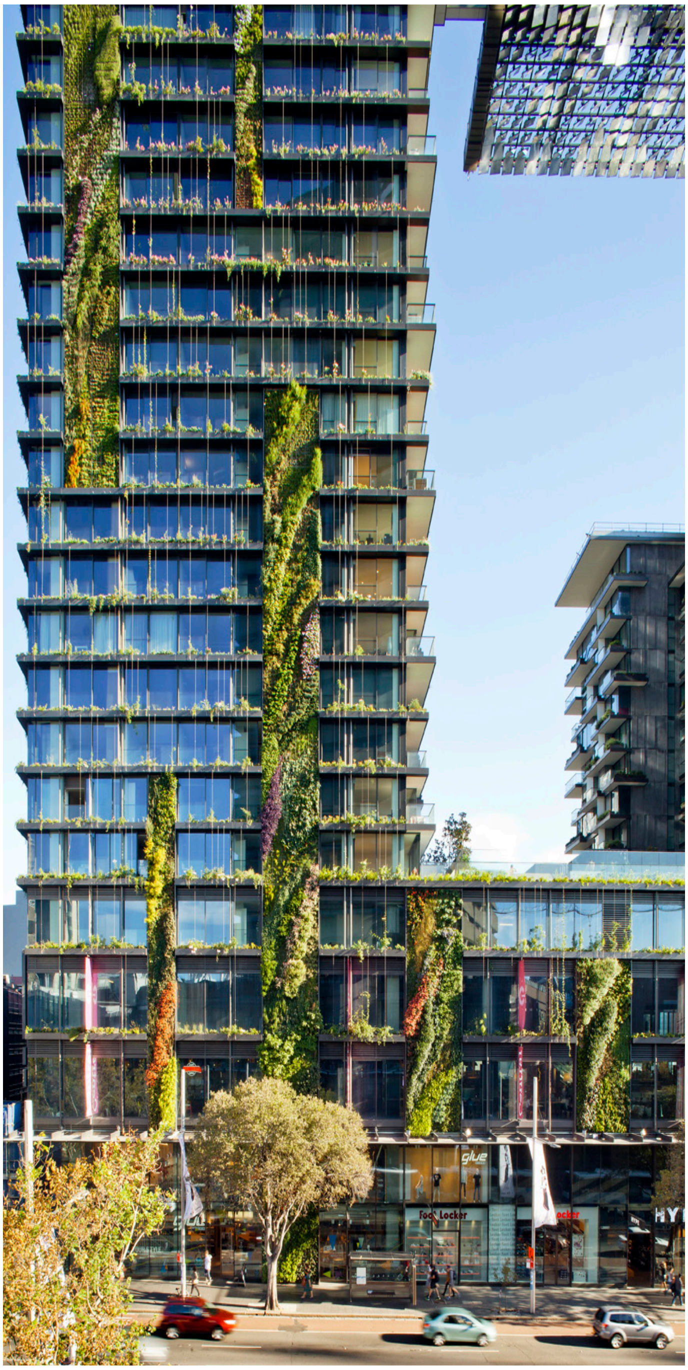
GREEN ROOF TYPE	PRIMARY REASON	CO-BENEFITS
1. Thermal	Improve insulation and reduce energy consumption	• Storm-water attenuation • Urban heat island • Bio-diversity • Air quality
2. Storm-water	Attenuate pluvial flooding	• Thermal improvement • Urban heat island • Bio-diversity • Air quality
3. Biodiversity enhancement	Increase local bio-diversity	• Air quality • Urban heat island • Thermal improvement • Storm-water attenuation
4. Conservation of endangered flora and fauna	Provide environment for endangered species	• Air quality • Urban heat island • Thermal improvement • Storm-water attenuation
5. Urban food production	Local food production	• Reduce carbon food miles • Air quality • Urban heat island • Thermal improvement • Increase bio diversity • Storm-water attenuation
6. Provision of social space	Amenity space	• Thermal improvement • Air quality • Urban heat island • Thermal improvement • Storm-water attenuation • Food production

(Source: Wilkinson & Dixon, 2016)

for implementation (City of Sydney 2017).

Stormwater management, dynamics, and monitoring are some of the critical challenges for green roofs. For example Sydney is predicted to get more intense rainfall in future which may lead to greater likelihood of flash flooding. Further training and skill development across the built environment stakeholders with regards to retrofitting green roofs for effective stormwater management is essential (Wilkinson et al. 2015). When assessing green roof retrofit potential, existing structural load bearing capacity, access to green roofs, power and water supply, orientation to sunlight, and occupational health and safety are determinants of suitability to retrofit, and of the type of green roof to install (Feitosa and Wilkinson 2016). The University of Melbourne and the Inner Melbourne Action Plan (IMAP) councils (2014) have jointly formulated 'Growing Green Guide' for plant selection for Melbourne and surroundings. A planting guide for plant selection considering climatic conditions, sunlight access and growing conditions and purposes of the green roofs, walls and facades such as storm water management, aesthetics, edible or non-edible planting and drought tolerance etc. are absolutely important for effectiveness and long-term survival of plants (University of Melbourne and IMAP 2014). An accurate evaluation method or tool for retrofitting considering climatic conditions, nature of building stocks, plant selection and other relevant factors for Australia needs to be developed. Sustainable adaptive practices are to be formulated for different categories of buildings such as residential, commercial and industrial and others. Limited understanding on and availability of these practices and tools pose significant challenges for the green roof industry.

One of the key concerns of the stakeholders and professionals is the high costs of the green roofs walls and facades installation and maintenance (Downton 2013; City of Sydney 2017; GSA 2011). Specialised knowledge and skills are needed for maintenance and care when these green roofs, walls and facades installed in high-rise buildings, such as One Central Park in Sydney. Easy accessibility for maintenance of green roofs, walls, and facades in indoor and outdoor environments should be considered for retrofitting existing and at the



One Central Park, Chippendale (source: S. Wood, n.d.)

design stage for new buildings. While assessing positive environmental contributions of green roofs in economic returns, these living architecture practices are subject to competition with other more established sustainable technologies and practices in the market such as alternative opportunities for solar water heating, solar PV installation (City of Sydney 2017) and energy efficient fixtures and appliances in the buildings.

Hopkins and Goodwin (2011) identified lack of structured methods and absence of data on material covers and environmental performance of green roofs is a problem for establishing quantitatively positive contributions of the green roofs. For example, the local economic potential of rooftop agriculture could be immense but has not been explored to a sufficient extent (Wilkinson & Page, 2015. GSA 2011). Developers often intend to consider other technologies as more feasible and likely to provide better economic values compared to green roofs, walls and façade technologies. Applications for green roofs have become limited to only to handful of best practice urban development projects (City of Sydney 2017). Continuing maintenance of plants is an added cost, and overall, the extensive cost of installing green roof is a major barrier to the uptake of green roofs. It essential to determine holistically short term and long term multiple performance benefits and associated economic and environmental values to establish the efficiency of green roofs, walls and façades. AECOM (2017) have estimated the value uplift of green infrastructure in the typical Sydney home to be in the order of $50,000 and Newell et al (2011) estimate the price premium in top quality commercial property for sustainability features to be around 9%. Further hedonic modelling of property prices and the amounts of green infrastructure would give more detailed knowledge of the value uplift and stimulate the market to invest in more green infrastructure.

The capacity of the construction industry with regards to green roofs is in a developing phase and not fully ready to roll out green roof or wall installation on a wider scale at building, precinct and city scales. The industry should be able to supply skilled workmanship and withstand the demand for green roofs. Community awareness for green roofs has developed to a reasonable extent, and people recognise the importance green roofs installation in Sydney (City of Sydney 2017). To date green roof policy approaches have been implemented in limited local governments in Australia. There is a lack of appropriate policy and regulations to integrate living architecture practices (green roofs, walls, and facades) at the design phase of new buildings and also to retrofit existing buildings. In 2016 an RICS Best Practice Guidance Note on Green Roofs and Wall (2016) was launched to provide guidance to surveyors (including valuers, quantity surveyors, building surveyors, property managers and facility managers) when advising clients on green roofs and walls.

Overall these are the challenges for implementation of living architecture practices and further work is necessary to address this substantial gap and formulate suitable planning policies, building standards and guidelines integrating green roofs, walls and facades. The barriers are summarised in table 2.

Table 2 Barriers to living architecture

TYPE OF BARRIER	DESCRIPTION
Economic	Perceptions about high installation and maintenance costs. Lack of knowledge regarding value uplift of green infrastructure to property capital and rental values
Environmental	Plant lifecycle and replacement rates Additional water consumption Additional energy consumption Competition with other sustainable technologies e.g., rooftop solar PV
Social	Occupational Health and Safety during installation and maintenance
Technological	Structural capacity for retrofit Leaks Reliability of systems – durability Reliability of systems – maintenance Access to roof for installation and maintenance Orientation (access to sunlight) Lack of guides for building owners and property managers / facility managers Construction industry capacity

(Source: authors)

3. Resilience and resilient cities

As the 21st century progresses, we are evolving collective thinking and responses to the challenges we face. This includes living with a changing climate, increasing global population and changing demographics, mass urbanisation, issues of inequality, instability, food security and increasing scarcity of resources, as well as an increased need for sustainability in the built environment (UN 2015. RICS 2015).

Climate change is one of the greatest challenges of our time. The World Bank Group Report (2015) on Building Regulation for Resilience: Managing Risks for Safer Cities noted in the last two decades natural disasters have claimed 1.3 million lives, affected 4.4 billion people and have created US$2 trillion of economic losses. High-income countries, with advanced building code systems experienced 47% of disasters, yet only 7% of fatalities, and thus a prima facie case exists for rigorous regulation (The World Bank Group, 2015). The World Bank Group called for a fundamental shift from managing disasters to reducing underlying risks. Increases in global temperature, sea level rise, ocean acidification and other climate change impacts are some of the 'chronic' stresses that seriously affect coastal areas and low-lying coastal countries. The survival of many societies and the planet's biological support systems, are at risk.

By way of response, the UN 'Transforming Our World: The 2030 Agenda For Sustainable Development' report (2015) stated that 17 Sustainable Development Goals and 169 targets demonstrate the scale and ambition of a universal Agenda (see figure 1). The goals and targets are integrated, indivisible and balance the economic, social and environmental dimensions of sustainable development. They will stimulate action to 2030 in areas of critical importance for humanity and the planet (UN 2015:1). Goal 11 relates most directly to the built environment and green infrastructure; to 'make cities and human settlements inclusive, safe, resilient and sustainable' (UN 2015). 'Inclusive, safe, resilient and sustainable' settlements and cities provide the setting for the delivery of many sustainable development goals. Goal 3 'Ensure healthy lives and promote well being for all at all ages', is clearly related, in part, to the quality of the buildings in which people live and work, as well as access to green space. Our role as built environment stakeholders is crucial and cannot be under-estimated.

Against this background, the focus is the role of green roofs and walls in contributing to these goals. Resilience is defined and explained and then related to green roofs and walls. The section is structured so that city scale solutions and research is covered firstly followed by individual building scale solutions.

Scale of the problem from city to building scale

It took hundreds of thousands of years for global population to grow to 1 billion, and in another 200 years it grew seven times (UN 2015). In 2011 world population was 7 billion, in 2015 it reached 7.3 billion, and is predicted to be 8.5 billion in 2030, 9.7 billion in 2050 and 11.2 billion in 2100 (UN DESA 2015). Growth is driven by greater numbers surviving to reproductive age, combined with changes in fertility rates, increasing urbanisation and accelerating migration. Such trends have far-reaching implications for the generations to come (UNPF, 2015).

The world is undergoing the largest wave of urban growth in history. More than half the world's population now live in towns and cities, and by 2030; this number will be circa 5 billion (UNFPA, 2015). By 2050, an estimated 66% of global population will be urbanised (RICS, 2015). Though much of this urbanisation will unfold in Asia and Africa, bringing huge social, economic and environmental transformations; all countries and cities will be affected.

Whilst urbanisation could usher a new era of well-being, resource efficiency and economic growth, cities house high concentrations of poverty and inequality. In some cities, wealthy communities coexist alongside, less advantaged ones. As our cities grow, in many cases, faster than ever before we need planning and governance to deliver transition from one level, scale and type of development to others at the city scale, ensuring infrastructure, including green infrastructure, can support growing populations and changing land uses. Within this adaptation of existing areas to accommodate greater numbers of people, and as the predominant land uses undergo change, we need to consider optimum levels of sustainable

Figure 1. UN Sustainable Development Goals

Sustainable Development Goals

Goal 1. End poverty in all its forms everywhere

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Goal 3. Ensure healthy lives and promote well-being for all at all ages

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all

Goal 5. Achieve gender equality and empower all women and girls

Goal 6. Ensure availability and sustainable management of water and sanitation for all

Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation

Goal 10. Reduce inequality within and among countries

Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable

Goal 12. Ensure sustainable consumption and production patterns

Goal 13. Take urgent action to combat climate change and its impacts[*]

Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development

[*] Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

(Source: UN Sustainable Development Goals, 2015).

development that includes, at the building level, different degrees of green infrastructure to new and existing buildings.

City Level Challenges

The 100 Resilient Cities (100RC), initiated by the Rockefeller Foundation (100RC, 2016) aims to assist global cities to meet the physical, social and economic challenges faced now, and in the future. Many cities are developing resilience plans, Sydney published its' preliminary assessment in 2016, whereas New York published its' strategy in 2013. The 100RC supports the adoption and incorporation of acute and chronic manifestations of resilience. Acute or shock events include bushfire, earthquakes and floods, whereas chronic stresses undermine and weaken the fabric of a city on a daily or cyclical basis. High unemployment levels; inefficient public transport systems and endemic violence are examples. By addressing shocks and the stresses, a city is more able to respond to adverse events, and better placed to deliver basic functions in good and bad times, to all populations. Melbourne was among the first wave of 32 cities to join the 100RC network and published its resilience strategy in May 2016.

The 100RC has identified and collated the challenges facing a number of global cities. Table 3 illustrates the two Australian cities, Melbourne and Sydney as well as the selected case study cities of London, Rotterdam, Singapore and Toronto, to highlight their challenges and the similarities and differences that exist. The issues range from social to environmental and economical, some are chronic where others are acute. Clearly adoption of green infrastructure including green walls and roofs sits within these circumstances. It follows that different solutions suit different cities and different locations and have different degrees of importance.

Many issues are shared, for example terrorism, whilst others are distinct such as Toronto with its over taxed, under developed, unreliable transportation system. Some cities have multiple issues such as Melbourne listing 14 whereas London lists four. Table 3 shows the resilience issues in the case study cities to illustrate the shared and distinct issues faced. Stockholm is not one of the 100RC and is not included in tables 3 and 4. These criteria may be significant in terms of those

Table 3 Resilience challenges faced in selected Australian and project case study cities

CITY	RESILIENCE CHALLENGES (100 RESILIENT CITIES)
Melbourne	1. Aging infrastructure 2. Coastal flooding 3. Declining or ageing population 4. Disease outbreak 5. Drought 6. Economic shifts 7. Heatwave 8. Lack of affordable housing 9. Rainfall flooding 10. Rapid growth 11. Rising sea level and coastal erosion 12. Social inequity 13. Terrorism 14. Wildfires
Sydney	1. Aging infrastructure 2. Heat wave 3. Infrastructure failure 4. Lack of affordable housing 5. Overtaxed/ under developed/unreliable transportation system 6. Rapid growth 7. Rising sea level and coastal erosion 8. Social inequity 9. Terrorism 10. Wildfires 11. Rooftop solar PV
London	1. Endemic crime and violence 2. Infrastructure failure 3. Lack of Affordable housing 4. Terrorism
Rotterdam	1. Coastal flooding 2. Drought 3. Hazardous materials accident 4. Heat wave 5. Rainfall flooding 6. Refugees

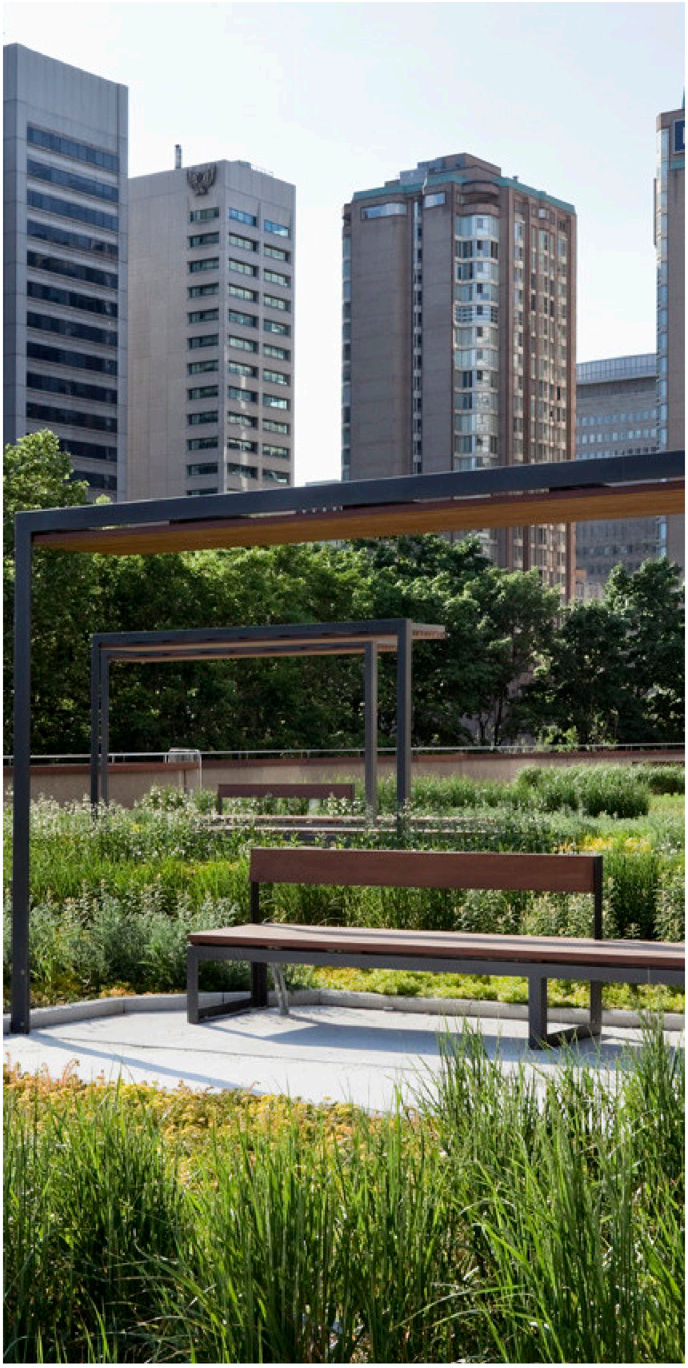
table continued on following page

CITY	RESILIENCE CHALLENGES (100 RESILIENT CITIES)
Singapore	1. Coastal flooding 2. Heat wave 3. Pollution or Environmental degradation 4. Rainfall flooding 5. Raising sea levels and coastal erosion 6. Terrorism
Toronto	1. Aging infrastructure 2. Blizzard 3. Economic inequality 4. Infrastructure failure 5. Lack of Affordable housing 6. Over taxed / under developed / unreliable transportation system 7. Rainfall flooding

(Source: 100 Resilient Cities, 2016)

cities who have or have not adopted mandatory or voluntary approaches to green roofs and walls.

Resilience scales refers to the different levels at which resilience issues impact and can be tackled. The smallest scale is building, followed by precinct or district, city, metropolitan area, country, region and finally the world. This shows how action taken at building levels is effective up the chain to global level. Figure 2 shows this model incorporated into the Rotterdam resilience strategy.



Nathan Phillips Square Podium green roof, Toronto (source: Evans, S.and Pommer, C.2011)

Table 4 Resilience issues and case study cities compared

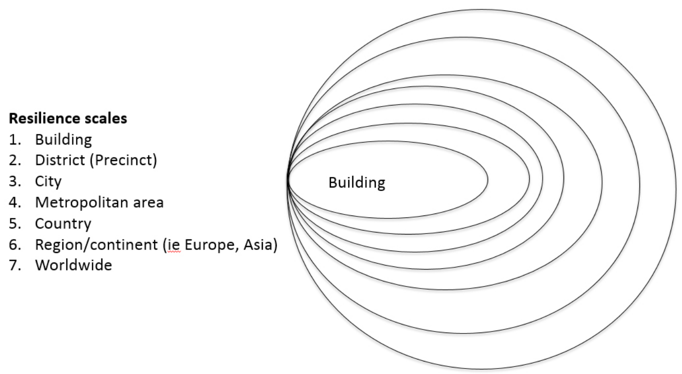
ISSUE	MELBOURNE	SYDNEY	LONDON	ROTTERDAM	SINGAPORE	TORONTO
Ageing infrastructure	●	●				●
Blizzard						●
Coastal flooding	●				●	
Declining or ageing population	●					
Disease outbreak	●					
Drought	●			●		
Economic Inequality						●
Endemic crime & violence			●			
Economic shifts	●					
Endemic crime & violence						
Heatwave	●	●		●	●	
Infra-structure failure			●			●
Lack of affordable housing	●	●	●			●
Overtaxed, underdeveloped unreliable transportation system						●
Rainfall flooding	●				●	●
Raising sea levels & coastal erosion	●	●			●	
Social inequality		●				
Refugees	●					
Terrorism	●	●	●		●	
Wildfires	●	●				

(Source: 100 Resilient Cities, 2016)

The notion of urban resilience

The notion of urban resilience has evolved in recent years and is used in policy and academic discourse (Urban Green Council, 2013; NSW Government Planning and Environment, 2014). The theory of resilience explains complex socio-ecological systems and their sustainable management; here urban settlements, cites and buildings. Theorists claim that systems change continuously in non-linear ways, and that resilience offers a framework for dealing with future uncertainties.

Figure 2 Model of Resilience Scales



(Source: Rotterdam Resilience Strategy, 2017)

Resilience is perceived as positive; taking action to make us less vulnerable to climate change, natural disasters and/or man-made disasters such as economic downturns or collapse. Resilience is an attractive perspective with regards to cities, which are complex adaptive systems (Batty, 2008). Urban settlements with over 50,000 people, account for 71% of global carbon emissions; yet cover only 3% of the area. In accommodating growth and expansion, cities and the buildings within them, need to possess resilience. Resilience is derived from the Latin word 'resilio'; which means to bounce back. In the 19th century, the term evolved to embrace adversity (Alexander 2013). The term is used by many disciplines, which each understand and interpret the notion differently. Meerow et al, (2016) found five themes as shared qualities of resilience, which are;

1. equilibrium versus non equilibrium,
2. positive versus negative conceptualisations of resilience,
3. mechanisms of system change (from persistence, transitional or transformative change),
4. adaptation versus general adaptability, and;
5. timescales of action.

Meerow et al (2016) posited a definition of urban resilience as; The ability of an urban system - and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales - to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity. The 100 Resilient Cities (100RC, 2016) defines urban resilience as 'the capacity of individuals, institutions, businesses and systems within a city to adapt, survive and thrive no matter what kind of chronic stresses and acute shocks they experience'. Both definitions view urban resilience as dynamic and changing.

In defining urban and the characteristics of urban settlement, many definitions posit that cities and urban systems are complex, networked systems (Desouza & Flanery 2013:91) and conglomerations of ecological, social and technical components. Ernstson et al (2010) claim cities are complex socio-ecological systems composed of socio-ecological and socio-technical networks. Cities and their hinterlands are highly inter-dependent with delineation of boundaries problematic, as some systems extend beyond the physical city limits such as water or food supply.

Equilibrium

Scholars debate issues of single state, multiple-state and dynamic non-equilibrium (Davoudi et al, 2012). Single state equilibrium is the ability to return to a previous state of equilibrium post disturbance and prevails in disaster management, for example, where an area and buildings are reinstated post flood. Multiple-state equilibrium acknowledges that there can be numerous states of equilibrium in any system. It has been accepted that systems exist in a state of dynamic non-equilibrium, that is no constant state can exist and there is a continuous state of flux and change. This leads to the rejection of the notion of resilience as 'bouncing back'. In this understanding of the term; systems are 'safe to fail' as opposed to fail safe, and acknowledge that post disturbance, cities and their buildings may not return to a previous state. Further a return to 'normal' may not be desirable and appropriate as the original state was vulnerable. A co-ordinated proactive approach to risk mitigation and adaptation within the urban planning and built environment is recommended (Sanchez et al, 2016).

Positive versus Negative notions
Resilience was perceived as positive in all 25 definitions analysed by Meerow et al (2016), where resilient systems maintained basic functions, prospered and improved. Other studies note some existing states are undesirable (Cote and Nightingale 2011), such as areas with inadequate, poor quality housing.

Mechanism of Change
There are three mechanisms of change or ways to resilience. Firstly 'persistence'; where efforts are made to return or maintain the built environment and its systems in an existing state, e.g., after a storm buildings are reinstated (Chelleri, 2012). Retrofit is an example of persistence. The second mechanism is 'transitional', which implies some adaptation to a new state or incremental change, e.g; change of use from a former land use of warehouse to residential as an area transitions post industrialisation. The third, most extensive change is 'transformative', e.g; where significant adaptive reuse occurs and areas are completely transformed.

Adaptation
Adaptation refers to the differences between high adaptedness compared to more generic adaptability (Elmquist, 2014). Wu and Wu (2013) argued too much emphasis on specified resilience undermines system flexibility and ability to adapt to unexpected threats. Others perceive adaptability as synonymous with adaptive capacity and note the importance of maintaining general resilience to unforeseen threats in addition to specified resilience to known risks. With known risks of pluvial flooding affecting a city, it involves taking measures in the design, construction and adaptation of buildings to reduce the risk of water damage, such as specifying a green roof and ensuring faster recovery when pluvial flooding occurs. Equally adopting flexible design and construction in buildings might accommodate a greater variety of alternate uses over time, thereby having adaptive capacity. Warehouse buildings are an example of a building design with good adaptive capacity; globally they are used as residential buildings, hotels, art galleries and retail centres.

Timescale
Some studies perceive immediacy and rapidity of recovery as essential characteristics, however it is dependent on whether the focus is on rapid onset events such as storms and floods or more long term gradual states such as changing climate (Wardekker et al, 2010). Second, the timeframe is unclear and can be hours, months or years. So reinstatement of energy supply following a storm would be delivered preferably within hours, whereas reinstatement of flood damaged buildings might take months. Further there is the question of reinstatement being a return to the 'prior state', or an improved and different state that would be more resilient to the same type of event. Sanchez et al (2016) note urban transformation requires active engagement in setting long term goals at city or state level, however flexibility is a pre-requisite to adapt to changes that occur otherwise unintended adverse consequences may result. Although these issues are dealt with at city or state level, it is at building level where many interventions and adaptations will occur.

Resilience is complex, with many attributes and levels of interpretation. Meerow et al (2016) stated it was vital to consider the who, what, when, where and why. In considering resilience be aware 'who' is determining what is desirable for an urban system, whose resilience is prioritised and, who is included or excluded from the urban systems? In respect of 'what'; what should the system be resilient to, what networks /sectors are included in the urban system, and this the focus on generic or specific resilience? The question of 'when'; is the focus on rapid or slow onset disturbances, on short or long term resilience, and finally on the resilience of current or future generations? The fourth W covers 'where'; in respect of the boundaries of the urban system, and whether resilience of some areas prioritised over others, and whether building resilience in some areas affects the resilience of other areas. Finally 'why'; what is the goal, what are underlying motivations and is the focus on process or outcome (Meerow et al, 2016).

Built environment resilience refers to the physical built environment that accommodates human activities, whereas community resilience refers to the resilience of individuals or a group of inhabitants and their social constructs. Here the literature is focused on notions of well-being, governance and economy. Sanchez et al (2016) give the example of built environment resilience different stakeholders having a different focus, with built environment resilience, engineers are focused on engineering infrastructure and restoration to operation as soon as possible after a disaster, whereas a community engineering resilience will focus on social and economic outcomes.

Green roof, MONA, Hobart (source: P. Osmond, n.d.)

4. International policy approaches

In this section of the literature review, we summarise international planning policy frameworks related to living architecture, at national and city levels. Our review shows that different international cities have different approaches to implement green roofs and walls. These approaches vary depending on a range of factors including governance structure, climate, location, proposed impacts from climate change and density of the urban form. The following five cities were selected for review:

- London, England;
- Rotterdam, The Netherlands;
- Singapore;
- Stockholm; Sweden
- and Toronto, Canada.

Below, we briefly discuss the different policy approaches taken by each city, and how they are framed. Detailed case studies are presented separately in the separate case studies document. A review of the policy framework and policies for Australian states is outlined separately in Section 5.

London, England

In London, there are three levels of governance: national, regional (Greater London Authority) and local (33 boroughs). While national Planning Policy Statements (PPS) and the Greater London Authority's provide policy guidance from higher governments, boroughs are responsible for planning within their local area. The Local Plan prepared by the City of London (2015) encourages green roofs and walls in its Core Strategic Policy CS19: Open Space and Recreation. The City of London encourages architects and developers to install green walls on buildings for environmental benefits (City of London, 2014). The City has also provided funding for green roofs and rain gardens (Greater London Authority 2017). One of the key drivers for implementing green roofs and green walls in London (as well as green infrastructure more broadly), is urban storm-water management. Managing overland flows during peak rainfall events, as well as water levels in the tidal River Thames, is critical to ensure the resilience of the city.

Rotterdam, The Netherlands

In Rotterdam, there are three levels of government: national, provincial and municipal. Planning for the city of Rotterdam is undertaken by the Municipality of Rotterdam. The key document for sustainable development in Rotterdam is 'Making sustainability a way of life for Rotterdam: Rotterdam Programme on Sustainability and Climate Change 2015-2018' (City of Rotterdam, 2016). This document was endorsed by the municipality in March 2016 and outlines the goal for implementation of green walls throughout the city. To achieve this goal, City of Rotterdam has implemented a series of tools including a grant / subsidy scheme, tax benefits, campaign periods, demonstration projects, information days and personal advice. In Rotterdam, there is a focus on green roofs more than green walls. This is because of their potential to manage urban stormwater, a key issue in the city, which sits an average of 5m below sea level. The government considers green roofs (and other green infrastructure elements) an important way of increasing the resilience of the city.

Singapore

Urban greening has been a key part of the government's plan for the city-state since 1968, when the country's founding Prime Minister, Lee Kuan Yew, announced his vision for Singapore, which centred around the idea of a 'garden city', to attract foreign investment and increase liveability. Singapore has established a comprehensive program to promote rooftop greening in order to reach its goal of 200 hectares of Skyrise Greenery by the year 2030 as outlined in the Sustainable Singapore Blueprint 2015 (Ministry of the Environment and Water Resources and Ministry of National Development, 2014). Singapore encourages green roofs through a wide variety of incentives, guidelines, policies and grants. These include the Skyrise Greenery Incentive Scheme (implemented by the National Parks Board), the Landscaping for Urban Spaces and High-Rises (LUSH) program (implemented by the Urban Redevelopment Authority), as well as the Landscape Excellence Assessment Framework (LEAF) certification program and the Skyrise Greenery Awards (implemented by the National Parks Board).

Stockholm

Stockholm is a metropolitan area housing over a fifth of Sweden's population. There are three tiers of governance at national, municipal and county levels. The municipality is responsible for regulations affecting planning and building and this is delivered through the Planning and Building Act. There are 26 municipalities within Stockholm, which is focussing on increasing densities and redeveloping land to accommodate a growing population. The city aims to be fossil free by 2050. The city acknowledges the role of the built environment to attenuate and mitigate the impacts of climate change and this is manifest in initiatives such as the Green Space Factor (GSF). The GSF and Green Points system, which originates in the GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco Towns) project is applied in urban regeneration schemes such as Hammarby Sjöstad and the Royal Seaport project. GRaBS is a network of pan-European organisations involved in integrating climate change adaptation into regional planning and development.

Toronto, Canada

Toronto has three levels of government: federal, provincial and municipal. The City of Toronto has responsibility for planning in the city. It is a large city with a very high-density downtown (CBD) area. As with many high-density cities, officials are mindful of the climate change and resilience issues that relate to their region and how they must be managed to ensure the city remains a viable functioning centre of government and commerce, as well as being a safe, desirable place for its inhabitants. Toronto acknowledged the need to increase green infrastructure in the early 2000s and enacted a bylaw in 2010 to require owners to install green roofs where certain conditions exist. This Bylaw requires green roofs on new commercial, institutional and residential development with a minimum Gross Floor Area (GFA) of 2,000m² as of January 31, 2010. It was extended from April 30th 2012, to require compliance with the Bylaw for new industrial development. A green roof screening form is a tool to determine whether an owner is required to build a green roof. Numerous tools (checklists, declaration forms and templates) and support is available to owners including financial grants and incentives.

Augustenborg Botanical Roof Garden, Malmo (source: L. Lundberg, n.d.)

As a result a high number of green roofs have been installed in the City. Table 5 provides a summary of the support instruments provided in the case study cities reviewed above.

Table 5 Green roof and wall support instruments in the international case study cities

SUPPORT INSTRUMENT	CITY				
	LONDON	ROTTERDAM	SINGAPORE	STOCKHOLM	TORONTO
PLANNING POLICY	●	●	●	●	●
GUIDELINES			●	●	●
GRANT SCHEME		●	●		●
TAX BENEFIT		●	●		
DENSITY BONUS			●		
DEMONSTRATION PROJECTS		●		●	●
PERSONAL ADVICE		●		●	●
PUBLIC AWARENESS CAMPAIGNS AND INFORMATION DAYS		●	●	●	●
AWARDS			●		
RESEARCH		●	●		

(Source: authors)

5. State policy in Australia

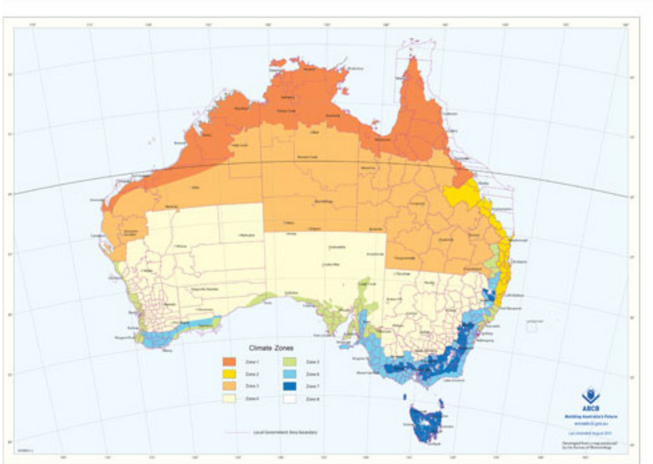
In this section, we discuss green roof and wall policy throughout a number of Australia's states. We review policy and other government documents from New South Wales, Victoria, South Australia, Western Australia and Queensland, that relate to green roofs and walls.

Australia has a three-tiered system of government: federal, state and local. There is no federal government policy on green roofs and green walls. Key documents relating to green roofs and walls produced by the federal government include the Living Wall and Green Roof Plants for Australia (Rural Industries Research Development Corporation, 2012) report and the Your Home: Australia's guide to environmentally sustainable homes guide (Department of Environment and Energy, 2013).

Each state in Australia has a different approach to policy for green roofs and green walls. Each state also has unique characteristics, including size, population, urban density and climate. At the state level, few specific green roof or green wall policies or planning instruments have been developed. However, recognition and support of green roofs and walls is underway, particularly in South Australia, Victoria and New South Wales.

Each state has also has a series of local governments which are responsible for planning across each local government area. While a review of local government policy is not the focus of this section, we do draw out key examples of green roof and wall policies implemented by the local governments of Australia's biggest cities – the City of Sydney and the City of Melbourne. Figure 3 illustrates the different climate zones across Australia and an indication that varying green roof and wall solutions are affected by location.

Figure 3. Climate zones across Australia



(Source: Australian Building Codes Board, 2015)

New South Wales

In New South Wales, the Department of Planning and Environment is the main agency responsible for developing policy which effects living architecture such as green roofs and green walls. There are no mandatory requirements for green roofs or walls on buildings in NSW. The NSW Department of Planning and Environment supports the implementation of green walls and roofs in its Draft Medium Density Design Guide (2016). Part 2C of the guidelines, Landscaped Area, advocates for building designs which incorporate opportunities for planting on structures, including green walls, green roofs and planter boxes. The State Environmental Planning Policy No. 65 – Design Quality of Residential Flat Development (SEPP 65) and its accompanying Residential Flat Design Code was introduced in 2002 by the department. In 2015, the Apartment Design Guide (NSW Department of Planning and Environment) replaced the Residential Flat Design Code. Two sections refer to green roofs and walls:

- Section 4.O 'Landscape Design' of the guide supports the use of green roofs and walls as part of environmentally sustainable landscape design and enhance environmental

performance.
- Section 4.P ‘Planting on Structures’ encourages plants on structures such as basement car parks, podiums, roofs and walls.

The New South Wales Office of Environment and Heritage (OEH) has taken a leading role in the development of guidelines around green roofs and green walls. The Urban Green Cover in NSW Technical Guidelines (OEH, 2015) advocates for the use of a range of green cover techniques (including green roofs and walls) to help ameliorate the urban heat island effect. These guidelines were produced to encourage industry and government to implement green cover in urban areas by increasing education and awareness. The NSW Environmental Trust, which sits within OEH, is currently finalising a blueprint for urban ecology in major cities across the state. Intensive green roofs and green walls are encouraged for their contribution to increasing urban biodiversity.

The Greater Sydney Commission (GSC) was established in 2015 by the Minister for Planning, to lead metropolitan planning in Sydney to improve productivity, liveability and sustainability. Two of the Commissions principal objectives are to encourage development that is resilient and takes into account natural hazards; and to support ongoing improvement in productivity, liveability and environmental quality. Living architecture can help achieve these objectives. Draft District Plans released by the GSC in November 2016 have no specific reference to green roofs or walls, although they do refer to the Urban Green Cover in NSW Technical Guidelines (OEH, 2015).

The Building Sustainability Index (BASIX) scheme was developed by the Department of Planning to help improve sustainability outcomes of residential properties in NSW. It sets energy and water use targets for single and multi-unit dwellings. Green roofs and green walls can contribute to thermal comfort and energy savings in residential buildings however they are not included in the assessment criteria. Figure 4 illustrates some NSW government documents which refer to green roofs and walls.

At the local government level, the City of Sydney leads the way in establishing a green roofs and walls policy for its local government area (LGA). It published the Green Roofs and Walls Strategy 2012 (City of Sydney 2012) to support the increase in the installation of green roofs and green walls in the LGA.

Figure 4. Some NSW government documents which refer to green roofs and walls

Living wall, Barangaroo, Sydney (source: Urban Developer, 2016)

Victoria

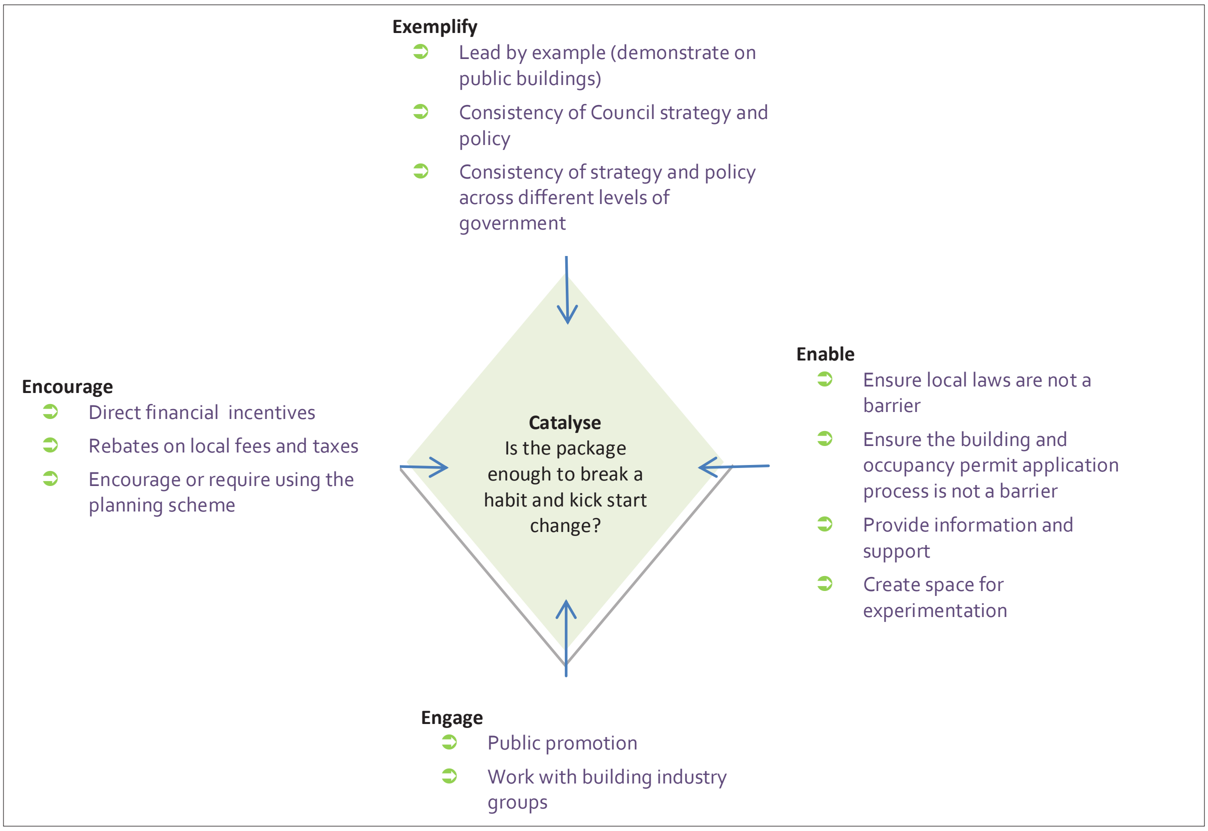
In Victoria, the Department of Environment, Land, Water and Planning is responsible for creating liveable, inclusive and sustainable communities. There are no mandatory requirements for green roofs or walls on buildings in Victoria. The Victorian State Planning Policy Framework currently does not include references to green roofs or walls. However, opportunities to integrate green roofs and walls have been identified in the Policy Options Paper, prepared as part of the Growing Green Guide for Melbourne project in 2013 (see figure 6).

The Better Apartment Design Standards (Department of Environment, Land, Water & Planning, 2016) came into effect in March 2017 when they were implemented through the Victoria Planning Provisions and all planning schemes. The design standards do encourage the use of green walls and greens roofs in apartment design. The landscape section of the standard states that:

- 'the landscape layout and design should … consider landscaping opportunities such as green walls, green roofs and roof top gardens to reduce heat absorption and improve storm water management' (p.17).
- 'If the development cannot achieve the deep soil areas specified in Table 1, an equivalent canopy cover should be achieved by providing either canopy trees or climbers (over a pergola) with planter pits sized appropriately for the mature tree soil volume requirements, or vegetated planters, green roofs or green facades' (p.18).

The Growing Green Guide for Melbourne project was funded by the Department of Sustainability and Environment under the Victorian Local Sustainability Accord. The Growing Green Guide (2014) is product of a collaborative partnership between four Inner Melbourne Action Plan councils - City of Melbourne, City of Port Phillip, City of Stonnington, City of Yarra - and The University of Melbourne. The document was produced for local and state government and industry to help increase the uptake of green roofs and walls throughout the state. It was developed for the design, construction and maintenance of green roofs and walls in Melbourne and Victoria more broadly. The project also explored policy options to support green roof,

Figure 5. Principles to support policy options green roofs, walls and facades



(source: Growing Green Guide Green Roofs, Walls & Facades Policy Options Background Paper, 2013)

Figure 6. Victorian Government green roofs and wall policy and reports

wall and façade development across Victoria, as mentioned above. The Growing Green Guide Green Roofs, Walls & Facades Policy Options Background Paper (2013) advocates the four "E"s of exemplify, enable, encourage and engage as principles to support policy for green roofs, walls and facades (see figure 5).

In terms of government funded research, the Victorian government funded the Victorian Centre for Climate Change Adaptation Research (VCCCAR) from 2009 – 2014. Funding was provided for research projects including green infrastructure and urban heat island mitigation.

At the local government level, the inner city councils in Melbourne lead the way in promoting green roofs and walls, as evidenced by the Growing Green Guide project.

Queensland

There are no mandatory requirements for green roofs or walls on buildings in Queensland. In Queensland, the Department of Infrastructure, Local Government and Planning is responsible for planning policy making. There is no policy for green walls and green walls for the state, or reference to green walls or green roofs in state planning policy.

Western Australia

There are no mandatory requirements for green roofs or walls on buildings in Western Australia. There is no policy for green walls and green walls for the state, however the draft Apartment Design: Volume Two of State Planning Policy No. 7.3 Residential Design Codes: Guidance for multiple-dwelling and mixed-use developments (Western Australian Department of Planning, 2016) contains a number of references to green roofs and green walls and facades. These include:

- Section 4.13 Roof Design. Objective 4.13.3 'Roof design incorporates sustainability features' encourages the design of roofs which feature green roofs for improved sustainability outcomes. (p.118)
- Section 4.14 Landscape Design. Objective 4.14.1 'Landscape design is viable and sustainable' also encourages the use of green roofs or green walls/facades and other vertical greening strategies. (p.120)
- Section 4.15 Planting on structures. Objective 4.15.3 'Planting on structures contributes to the quality and amenity of communal and public open spaces' encourages green roofs and walls for the social and aesthetic benefits that they provide. (p.122)

South Australia

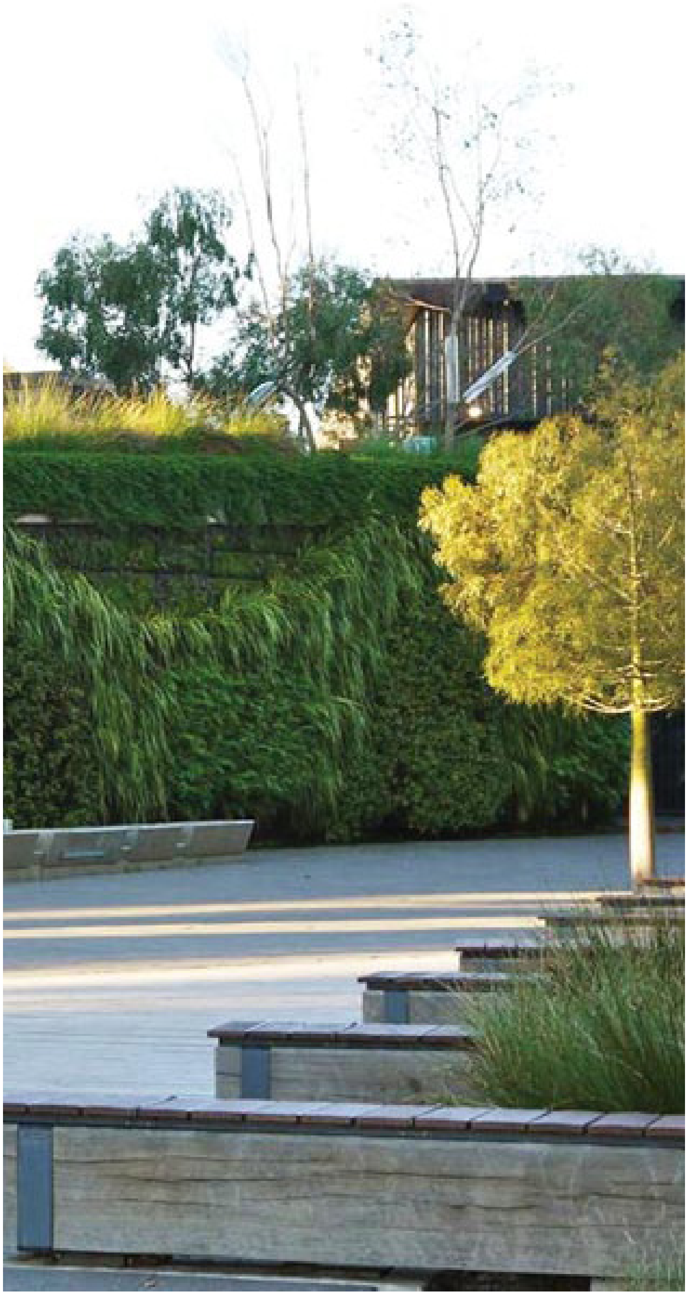
There are no mandatory requirements for green roofs or walls on buildings in South Australia. In South Australia, proposed green walls and roofs need to meet the requirements of the Development Act 1993; the Environment Protection Act 1993; the Natural Resources Management Act 2004; the Local Government Act 1999; and the Public and Environmental Health Act 1987.

The South Australian Department of Planning and Local Government provides free professional design services for state government buildings wishing to incorporate green roofs and walls. The Bushtops for Green Roofs and Walls incentives program allows access to concept design and development services via Planning SA's Principal Urban Designer's expertise in green roof and living wall design Hopkins, 2008).

The South Australian government also established the sustainability Building Innovation Fund (BIF) to fund demonstration projects featuring innovative, new, cutting-edge ways to reduce the carbon footprint of existing commercial buildings. The fund provided $2 million worth of grants between 2008 and 2012. The grants were offered to owners of office buildings and some hotels and shopping centres. The fund supported the commercial property sector agreement between the South Australian Government and the Property Council of Australia (South Australian Division) made under South Australia's climate change legislation. These incentives programs supported and enabled the creation of new roofs gardens throughout the state. For example, the BIF provided financial assistance for the green roof on the GP Plus Health

Care Centre in Marion.

The Technical Manual for water-sensitive urban design in Greater Adelaide (Department of Planning and Local Government, 2010) helps councils and planners apply WSUD to developments and buildings in Greater Adelaide. The Manual discusses green roofs in the context of stormwater management for their potential to reduce runoff volume and improve runoff quality. However, the document Water sensitive urban design: Creating more liveable and water sensitive cities in South Australia (Department of Environment, Water and Natural Resources, 2013) makes no reference to green roofs or green walls.



Green wall at Adelaide Zoo (source: Fytogreen, 2016)

6. Mandatory or voluntary approaches to green roofs and green walls

In Australia, constructing green roofs and green walls is voluntary. There are no policies or legislation requiring green roofs or walls. International case studies reveal a mix of mandatory and voluntary approaches to the implementation of living architecture in cities across Europe, Asia and North America. This section reviews a number of types of mandatory or voluntary policy approaches which have been used globally. There are four different types of policy instruments:

1. Information and advocacy
2. Incentives
3. Government demonstration and provision
4. Regulation (Maddison and Denniss, 2009)

For each of these different types of policy instruments, there are a range of mechanisms which can be implemented. They are summarised below in table 6. Mandatory approaches fall into the regulation category, while voluntary approaches can be information and advocacy, incentives, or government demonstration and provision.

Mandatory

Europe leads the way in mandating green roofs, especially in cities throughout Germany where mandatory green roof regulations have been in place locally and nationally for over thirty years (Ansel and Appl, 2009). For example, in Munich, all suitable flat roofs over 100m² are to be installed with a green roof. In Stuttgart, all new developments with flat or pitched roofs (up to 12 degrees) are required to be greened to specific standards (IGRA, n.d.). Since 1993, when the Federal Nature Conservation Act was introduced, the city has required that

Table 6 Green roof policy mechanisms

Policy instrument	Advocacy	Incentive	Government provision	Regulation
Community information, engagement, participation	✓			
Guidelines and toolkits	✓			
Incentives during the planning process for proposals that incorporate green roofs: • Increased floor area ratios • 'Green door' fast tracking of planning approvals • Waiving planning fees • Exempting certain works related to green roofs		✓		
Stormwater fee discount with increased pervious surfaces		✓		
Grants, rebates, financing for installation		✓		
Leadership, including demonstration green roofs			✓	
Integrated government decision-making on urban infrastructure and land use planning			✓	
Integrated government decision-making: ensure existing regulations do not pose a barrier for green roof installations			✓	
Mandatory green roofs/rooftop landscaping on all new buildings (may only apply to specific building types, such as commercial, multi-residential, or to buildings above a certain threshold area)				✓
Planning scheme overlays (identifying specific areas for mandated green roofs on new buildings)				✓
Green building certification (voluntary or mandatory sustainability rating schemes)		✓		✓
Data collection, monitoring, evaluation	✓		✓	
Research	✓		✓	
Awards, recognition programs	✓	✓	✓	

(source: Pianella et al. 2016, p. 800)

all new buildings be 'greened' as compensation for the loss of valuable habitat and green space. The city council provides a 50% reduction in stormwater fees for green roofs as well as direct financial incentives (subsidies) for the cost of installation and materials. In Berlin, the subsidy program 'Courtyard Greening Program', implemented between 1983 and 1996, was designed to encourage greening of courtyards, as well as the roofs and walls associated with them, to improve urban climate, quality of life for residents, and urban appearance. During the period of the program, 54 ha of courtyard and roofs were greened and 32.5 ha of facades were greened. On average, each square meter was subsidized with 19.10 € which included separate amounts for construction and design (Ngan, G. 2004).

Other cities throughout Europe have also mandated green roofs. For example, in Basel, Switzerland, the city's building and construction law was amended in 1992 to include the requirement that all new and renovated flat roofs be greened. The purpose of increasing green roofs in the city was originally initially driven by energy-saving programmes, and subsequently by biodiversity conservation (Kazmierczak, A. and Carter, J. 2010). The City of Basel has also used incentive programs, awards and grants to help promote green roofs. Researchers from the Zurich University of Applied Sciences also played a key role. They worked to influence decision-makers in Basel to amend the building regulations and offer financial incentives to increase green roof coverage. In Linz, Austria, green roofs are required on new buildings, with reimbursement of up to 5% (reduced from 30% in 2005) of the cost of green roof installation as an incentive. In Copenhagen, Denmark, all new roofs with a roof pitch under 30° are to be landscaped, providing there is no structural engineering reason preventing it. Since 2010 green roofs have been mandated in most new local plans.

In North America, Toronto made green roofs compulsory in 2009. It was the first North American city to pass a by-law requiring green roofs on new building developments. New residential, commercial and institutional buildings with a minimum Gross Floor Area (GFA) of 2,000m² are required to install a green roof, or pay a penalty for not doing so. Requirements for green roof coverage increase with building

Green wall, The Commons, Melbourne (source: Wuttke, A. n.d.)

footprint sizes and can only be reduced with financial penalty and permission from the chief planner. Since April 2012, green roofs are required on all new industrial buildings (City of Toronto, 2017).

In Asia, skyrise greening is compulsory on all government buildings in Singapore. In Tokyo, Japan, the impact of the urban heat island effect led to the government establishing an informal incentive program that provided a free consulting service. This was followed by a subsidy program which resulted in 7000m² of rooftop greening (Urbis, 2007). Tokyo then accelerated the process by mandating that all new private buildings larger than 1000m² and public buildings larger than 250m² must green 20% of the rooftop or pay an annual penalty of US$2000. In the first year (2000 to 2001) this law had a dramatic effect when it doubled the net area of green roofs in the city from 52,400m² to 104,400m² (Urbis, 2007). The Green Tokyo Plan (2000) set the goal of 1,200 ha (12,000,000m²) of rooftop greenery by 2015. The government has also constructed a series of demonstration projects on public buildings to encourage uptake (IGRA n.d.).

Voluntary

There are a host of cities across the world which have voluntary approaches to green roof policy. They often implement incentives such as grants, subsidies, free consultation services, tax reductions to promote the construction of green roofs and walls.

In the United States, the cities of Portland and Chicago have employed a range of voluntary policy mechanisms to encourage the uptake of green roof and walls. Between 2008 and 2012, Portland put in place the Eco-roof floor area ratio (FAR) bonus which allowed developers an extra 3 square foot per foot of green roof without additional permits (City of Portland, 2017). The city also offer grants for reducing storm water runoff by installing a green roof, and all city owned buildings are required to have 70% roof coverage with an eco-roof. In Chicago, the city provides financial assistance for buildings meeting specific green roof and efficiency criteria, and has established a green permit program for fast tracking planning permits (City of Chicago, 2017). The City of Chicago grants a density bonus option to developers whose buildings have a minimum vegetative coverage on the roof of 50% or 186 m² (whichever is greater), usually in the form of a green roof, as well as a storm-water retention credit for green roofs. The City also created a demonstration project in 2001 when it established a green roof on its city hall (American Society of Landscape Architects, 2002).

In Europe, the City of Rotterdam has used its strategic planning document 'Making sustainability a way of life for Rotterdam: Rotterdam Programme on Sustainability and Climate Change 2015-2018' to set the goal for living architecture. It has implemented a series of policy mechanisms including grants, a subsidy scheme, tax benefits, campaign periods, demonstration projects, information days and personal advice. In Italy, the city of Faenza has established a bio-neighbourhood incentive program for developers as part of its planning regulations. As part of the program, if developers create buildings with green roofs, walls and water retention systems, in addition to contributing to public green spaces, then they are allowed to extend the external surface area of their buildings in excess of approved standards (City of Melbourne, n.d.).

In Asia, Singapore leads the region with its implementation of living architecture. There are a wide range of voluntary policy mechanisms in place including grants, awards programs, certification schemes and GFA density bonuses. Section 5 and the Case Studies details this further. In Hong Kong, the government has a well established program of roof and vertical greening for government buildings. The Government has been incorporating roof greening designs where practicable into appropriate new government building projects since 2001. This includes schools, crematoria, hospitals, offices and community centres. Since 2006, the government has also been retrofitting government buildings with roof greening, and since 2008, vertical greening has been adopted in some government capital works projects including schools and government buildings (GovHK, 2016).

7. The business case

This section of the literature review explores the business case for expanding the living architecture industry in Australia by first identifying key ways that living architecture has been found to produce value, and second by presenting some findings from relevant attempts to evaluate the cost benefit analysis (CBA) of living architecture. Our analysis suggests that there are substantial opportunities for market growth in the living architecture industry.

Key ways in which living architecture delivers value

There are many economic, social and environmental benefits, which result from the installation of green roofs and walls. These benefits are either tangible which can be quantified or non-tangible, and not possible to quantify.

The accelerating rate of investment into Green Infrastructure is indicative of the value created for the diverse range of stakeholders who benefit. A key challenge to more widespread adoption of green walls and roofs is the clarity of the business case for specific investments, which are open to wide variety of design choices which affect the cost and benefits. Table 7 below provides a summary of key sources of value created from green architecture identified in the literature.

Notably, economic benefits can be divided into two categories;

1. **Those that benefit owners / occupants / investors directly** such as installation, replacement and repair, stormwater, include increases in property values, and energy savings leading to reduced operating costs for running less air conditioning in warmer months and less heating costs (through less heat loss through the external

Table 7 Summary of key drivers of value from green architecture

Value drivers	Main category of value delivered		
	Economic	Environment	Social / community
Supply of products and services			
Sale of fruit and vegetables	●		
Sale of flowers and other non-edible products	●		
Other value added products and services, such as provision of education services	●		
Direct cost savings			
Thermal energy saving leading to reduced demand for heating and cooling	●	●	●
Roof longevity in some cases	●	●	
Air quality			
CO2 sequestration and absorption			●
Removal of VOC (indoor and outdoor)		●	●
Quality of life			
Mental Health benefits such as reduced anxiety			●
Productivity benefits from increased amenity	●		

Value drivers	Main category of value delivered		
	Economic	Environment	Social / community
Stormwater management			
Absorption and storage of rain water leading to reduced demand from water supply	●	●	
Absorption and storage of rain water leading to reduced demand for stormwater services to manage urban water	●	●	
Reduction in urban water pollution such as through remediation of water quality	●	●	
Biodiversity			
Increased habitat		●	
Increased diversity in flora and fauna		●	
Urban Heat Island effect			
Reduce energy demand for cooling	●	●	
Acoustics			
Reduction of noise transfer			●
Tourism			
Increased direct and indirect employment and other economic activity	●		●
Real estate value			
Increase in property value	●		
Increase in surrounding property value	●		
Increased rent returns and reduced vacancy rates	●		
Increase in urban aesthetic			●
Other economic value			
New jobs for building infrastructure	●		
New jobs maintenance	●		

(source: authors)

walls and roofs);
2. **Other financial impacts** such as greenhouse gas savings, market based savings and community benefits.

A difficulty in quantifying the value from living architecture is that there are a variety of approaches to evaluate the net value. The most common approaches include cost-benefit analysis (Eckstein 1958; Prest and Turvey 1965, Pearce 1998), triple bottom line (Elkington 1997) and various combinations of life cycle assessment (LCA) and life cycle costing (LCC). As argued by Brown et al (2016), while these models enable analysis of the costs and benefits, they all are incomplete on some dimension, and hence have been criticised for not being sufficient in allowing for reliable evaluation of trade-offs between economic and environmental performance (Pearce 1976; Rambaud and Richard 2015; Brown 2016). For example, the economist David Pearce (1976) argued that conventional financial cost benefit analysis was not a sufficient basis for analysis of investments, largely because environmental costs and benefits are not included in the modelling. In the case of green architecture, this challenge is particularly salient as there are substantial direct costs incurred by property owners and investors (Downton 2013; City of Sydney 2017; GSA 2011), whereas the value created is shared by a range of different stakeholders including building tenants, the local community including the local economy. Perhaps in recognition of the shared value, a range of subsidies have been implemented to compensate investors. While more recent attempts to evaluate the business case for green architecture have included attempts to identify and quantify the value created with respect to economic, environment, and community / social value (e.g. GSA 2011), a more compressive approach which includes a more comprehensive set of value drivers is necessary.

Quantifying the value from living architecture

In this section we present the findings from some notable studies which provide an indication of the magnitude of the value created in some of the domains listed in table 7. A study in Toronto, Canada, modelled the effect of green roofs on the urban heat island. It concluded they would reduce local

Beare Park Amenities building, Elizabeth Bay (source: Fytogreen, n.d.)

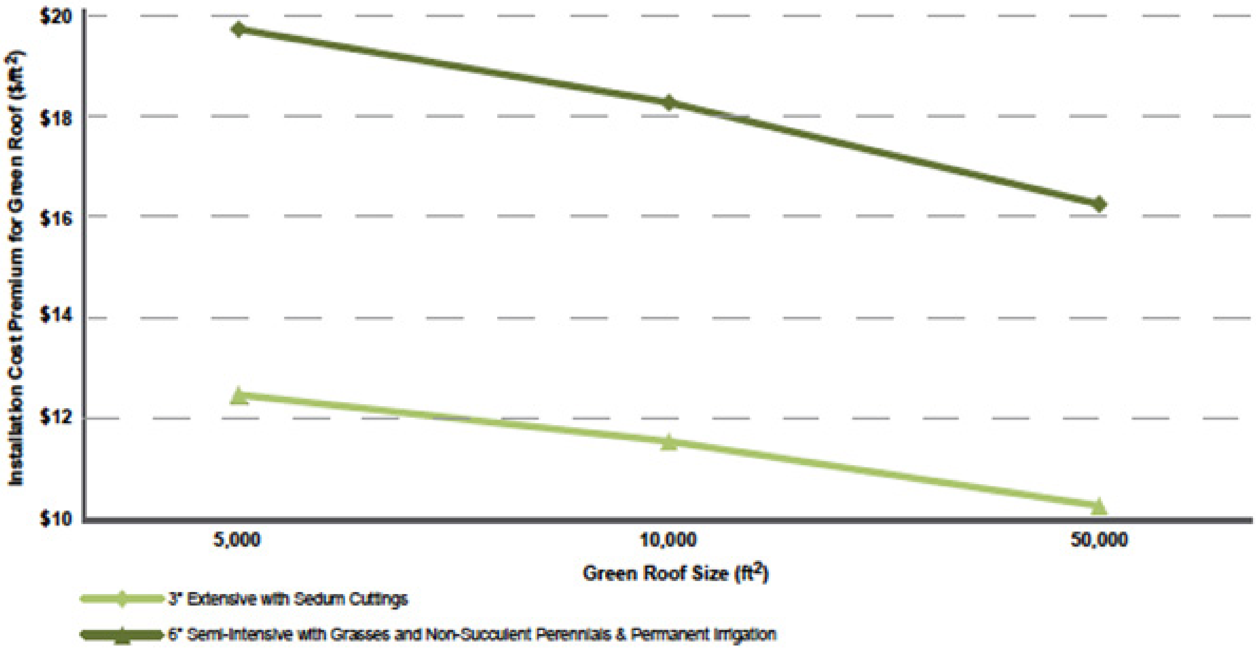
ambient temperature by 0.5°C to 2°C. The study calculated that this would result in C$12m of savings from reduced energy demand for cooling (Banting et al. 2005).

Canadian research has also estimated that buildings with a recreational green roof increase the property value by 11%, and that buildings with views of green roofs have a 4.5% increase in property value (Tomalty and Komorowski 2010). Peck et al (1999) estimated green walls increased Canadian property values between 6 and 15% with a midpoint of 10.5%. Des Rosiers et al (2002) estimated a more modest 3.9% increase in residential property in Quebec with green walls. To date, no research has examined economic impact of green walls or green roofs on Australian property values.

Perini et al (2011) examined vertical greening systems and the effect on airflow and temperature on the building envelope in a Mediterranean climate and Mazzali et al (2012) conducted studies into the thermo-physical performances of living walls via field measurements and numerical analysis. Their studies estimated savings of 40-60% on demand for air-conditioning. Three out of four Australians had a refrigerated cooler by 2014, and in 2009 in Victoria the average use was 107 hours of air conditioner use in warmer months, with older and unwell people have much higher rates of use, some 10 to 15 times higher (Summers and Simmons 2009). Economic modelling estimated that average costs for people running air conditioners were between $49 and $66 (based on $0.15 and $0.20 per kWh respectively). Costs can be up to 64% higher in the hotter areas such as Queensland and 61% lower in cooler areas such as ACT. For 2007, the estimated average cost of cooling for all Australian households was $49–66, which is now approximately $62-84 adjusted for inflation (ABS 2017; Summers and Simmons 2009). Another estimate by Sustainability Victoria in 2017 stated typical monthly costs for air conditioning in the State are $32 per month at the most expensive and at least $2.25 per month (CanStar Blue 2017). Therefore applying 50% savings of $16 to the highest costs are possible with green wall retrofit, so for Melbourne's 4.82 million population based on 75% usage total monthly savings of $57.84M are possible. For the least cost rate 50% savings of $1.12 to the least costs are possible with green wall retrofit, so for Melbourne's 4.82 million population based on 75% usage total monthly savings of $4.04M are possible. Similar savings are possible in Sydney.

To the authors knowledge, the most comprehensive a cost-benefit analysis to determine costs and benefits of green roofs compared to traditional, or black, roofs is a US study in 2013 (GSA 2011). Unsurprisingly, they find costs vary based on roof

Figure 7 Green roof costs



(Source: GSA 2011)

type (intensive or extensive) and size of roof, diminishing on a cost per foot as size increases (see figure 7).

The costs and numbers of maintenance visits are shown in table 8.

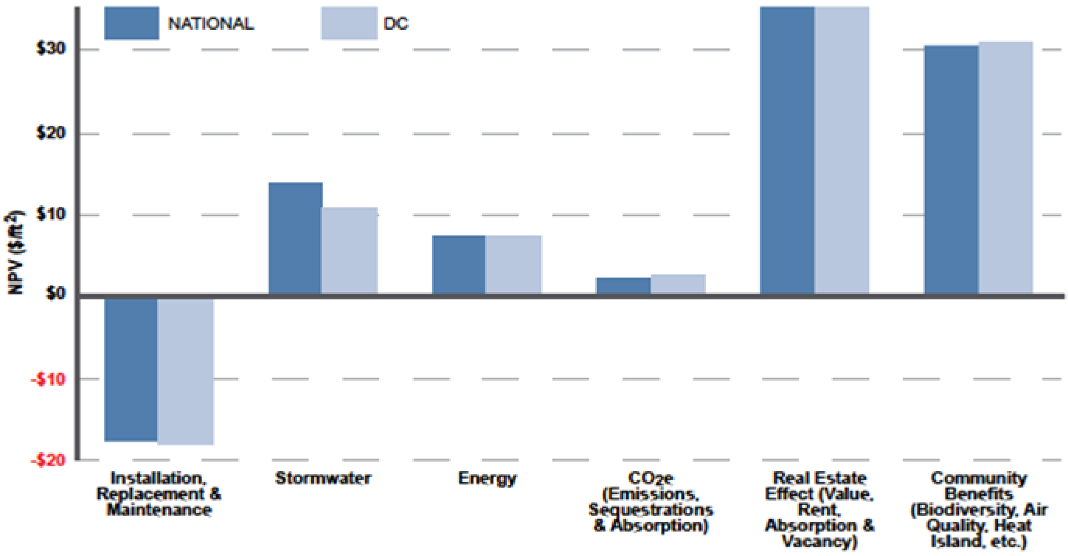
Table 8 Costs of installation and maintenance for intensive and extensive green roofs for CBA (source: GSA 2011).

Extensive roof
Installation costs /m² Annual maintenance 0.21 - 0.31 cents/sq ft. Year 1 set up = 3 visits crew of 2 Labour = 4hrs pp / sq ft or, 1.3 hours hrs/pp /1000 sq ft / visit 2 visits per year thereafter
Intensive roof
Installation costs /m² Annual maintenance 0.21 - 0.31 cents/sq ft. Year 1 set up = 4 visits crew of 2 Labour = 6hrs pp / sq ft or, 1.5 hours hrs/pp /1000 sq ft / visit 3 visits per year thereafter

(source: GSA 2011)

Figure 8, Tables 9 and 10 presents a summary of their estimate of net present value (NPV), which is a measure of the potential profitability of an investment. NPV takes the expected value of the future costs and benefits associated with an investment and accounts for the effect of inflation. A positive NPV means the investment will produce greater returns over the timeframe being considered than an alternate investment. Over a 50-year period, the installation, replacement and maintenance of a green roof has the greatest negative impact on net present value at a cost of approximately US$18 per square foot of roof. Stormwater and energy savings make up for this cost by providing a benefit of approximately US$19 per square foot of roof. Benefits to the community have the greatest positive impact on net present value at a savings of almost US$38 per square foot of roof.

Figure 8. NPV CBA results of green roofs versus traditional black roof in US.



(Source: GSA 2011).

Table 9 NPV CBA results of green roofs versus traditional black roof in US.

NATIONAL LEVEL RESULTS	ROOF SIZE (ft²)		
	5,000	10,000	50,000
Impact on Owners/Occupants/Investors			
Initial Premium, $/ft² of roof (extra cost of installing a green roof instead of a black roof)	-$12.6	-$11.4	-$9.7
NPV of Installation, Replacement, & Maintenance, $/ft² of roof	-$18.2	-$17.7	-$17.0
NPV of Stormwater, $/ft² of roof (savings from reduced infrastructure improvements and/or stormwater fees)	$14.1	$13.6	$13.2
NPV of Energy, $/ft² of roof (energy savings from cooling and heating)	$6.6	$6.8	$8.2
Net Present Value (installation, replacement & maintenance + stormwater + energy NPV)	$2.5	$2.7	$4.5
Internal Rate of Return (IRR)	*5.0%*	*5.2%*	*5.9%*
Payback, years	*6.4*	*6.2*	*5.6*
Return on Investment (ROI)	*220%*	*224%*	*247%*
Other Financial Impacts (less realizable)			
NPV of CO_2e, $/ft² of roof (emissions, sequestration & absorption)	$2.1	$2.1	$2.1
NPV of Real Estate Effect, $/ft² of roof (value, rent, absorption & vacancy)	$120.1	$111.3	$99.1
NPV of Community Benefits, $/ft² of roof (biodiversity, air quality, heat island, etc.)	$30.4	$30.4	$30.4

(Source: GSA 2011).

Table 10 NPV CBA results of green roofs versus traditional black roof in Washington DC

WASHINGTON DC RESULTS	ROOF SIZE (ft^2)		
	5,000	10,000	50,000
Impact on Owners/Occupants/Investors			
Initial Premium, $/ft² of roof (extra cost of installing a green roof instead of a black roof)	-$10.7	-$9.5	-$8.0
NPV of Installation, Replacement, & Maintenance, $/ft² of roof	-$18.1	-$17.9	-$17.7
NPV of Stormwater, $/ft² of roof (savings from reduced infrastructure improvements and/or stormwater fees)	$11.0	$10.5	$10.2
NPV of Energy, $/ft² of roof (energy savings from cooling and heating)	$6.8	$6.8	$8.3
Net Present Value (installation, replacement & maintenance + stormwater + energy NPV)	-$0.2	-$0.6	$0.7
Internal Rate of Return (IRR)	*4.3%*	*4.2%*	*4.7%*
Payback, years	*6.6*	*6.5*	*6.0*
Return on Investment (ROI)	*198%*	*194%*	*209%*
Other Financial Impacts (less realizable)			
NPV of CO_2e, $/ft² of roof (emissions, sequestration & absorption)	$2.6	$2.6	$2.6
NPV of Real Estate Effect, $/ft² of roof (value, rent, absorption & vacancy)	$98.4	$88.2	$74.1
NPV of Community Benefits, $/ft² of roof (biodiversity, air quality, heat island, etc.)	$30.9	$30.9	$30.9

(Source: GSA 2011).

The Internal Rate of Return (IRR), a measure of the expected annual financial benefit yielded by an investment over a given time frame (e.g., an IRR of 5% implies a stream of cash growing, on average, at 5% per year) is also calculated. This benefit can be compared with the expected yields of other investments over the same period. Payback is the number of years it takes to recoup an initial investment through the income from that investment. Finally the Return on Investment (ROI) is calculated; this is the percentage of money gained, or lost, on an investment, relative to the initial cost. In regards to the ROI, on a national level, a dollar invested in a green roof today suggests a return of $1.29 in today's dollars after 50 years. For Washington DC, the same dollar invested would yield one dollar in return (in today's dollars); in other words, the green roof investment is the same as an average, alternative investment of 4.4%. If CO_2e and community benefits were added in, that same dollar invested would result in US$3.19 and US$3.57, respectively. A sensitivity analysis was conducted to identify the more important variables based on their ability to impact the total NPV (presented in table 11).

Table 11 Sensitivity of the influence of changes in key variables on NPV

HARD COST VARIABLES	CHANGE IN TOTAL NPV PER 1% CHANGE IN VARIABLE
Roof Longevity (1-year change)	13.24%
Installation Costs	11.32%
Discount Rate	4.89%
Maintenance Costs	3.38%
Energy Savings	2.51%
Stormwater Equipment Cost	1.44%
Stormwater Surcharge	1.35%
Green Roof Risk Contingency	1.21%

(Source: GSA 2011).

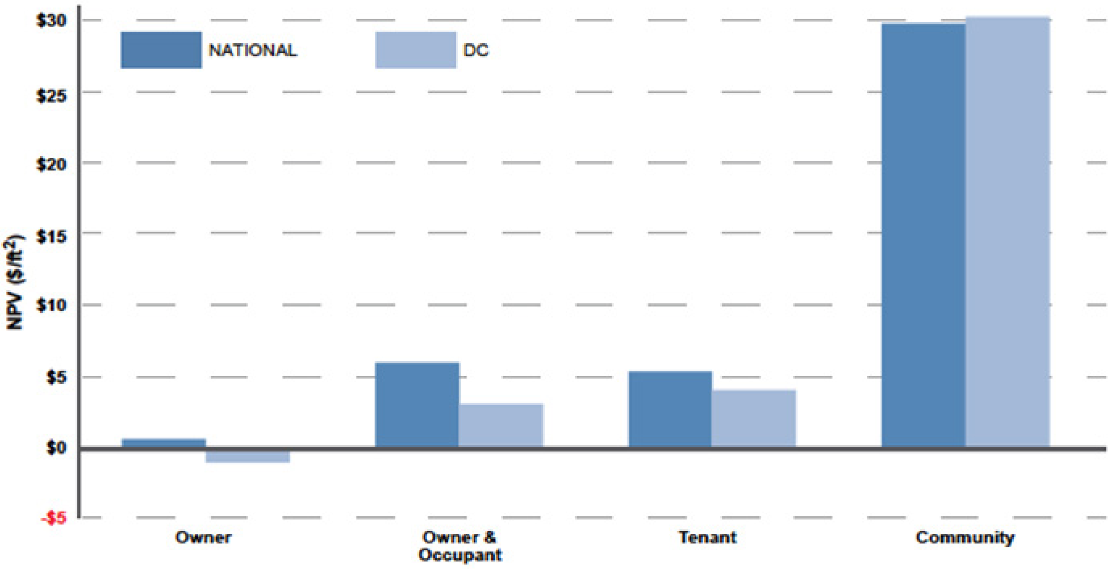
The results in Table 12 and Figure 9 indicate NPV per square foot of roof based on relationship to real estate.

Table 12 NPV of a green roof based on relationship to real estate

	OWNER	OWNER/ OCCUPANT	TENANT	COMMUNITY	MARKET EXPECTATION (YEAR 1)
NATIONAL	$0.06	$6.0	$5.4	$29.8	$12.9
WASHINGTON DC	-$1.0	$3.1	$4.1	$30.3	$10.0
TOP 2 DRIVERS	Maintenance Costs & Avoided Stormwater Infrastructure	Maintenance Costs & Avoided Stormwater Infrastructure	Maintenance Costs & Energy Savings	Biodiversity & Urban Heat Island	Longer leases & Rent

(Source: GSA 2011).

Figure 9 NPV of a green roof based on relationship to real estate



(Source: GSA 2011).

The additional cost of green roof installation is mostly made up for by its increased lifespan or longevity; however, added maintenance costs are significant (GSA 2011). Over a 50- year period, the stormwater, energy, carbon dioxide equivalent (CO2e), which measures the potential global warming effect of a greenhouse gas) and community earnings of green roofs more than compensate for the increased premium of installation and maintenance.

Building and site characteristics, stormwater regulations and energy costs vary considerably, long-term savings of green roofs compensate for maintenance costs. The fewer floors a building has, the greater the energy savings will be as the roof to floor area ratio is greater. Also the greater the surface area of a green roof as a proportion of overall site surface area, the greater the stormwater management savings will be. These savings are predicted to increase as stormwater regulations become more stringent over time and green roofs are increasingly viewed as an acceptable stormwater mitigation measure (Wilkinson & Dixon, 2016). As energy prices increase, the energy-related savings will increase also.

Additional analysis suggests the costs and benefits vary significantly depending on stakeholder perspective. Owner/operators might yield strong financial benefits from replacing non-green roofs of their assets with green roofs. GSA estimated (2013) in the National Capital Region of the US, if green roofs were to replace conventional roofs on all 54 million square feet of real estate (approximately 5.9 million square feet of roof area), their CBA projects a 50- year NPV of US$22.7 million, or US$0.42 per square foot of building area. The community benefits in the National Capital Region could total almost US$180 million, or US$3.30 per square foot of building area. To date this calculation has not been undertaken for Melbourne or Sydney.

Consideration should be given to competing initiatives. The GSA CBA did not consider whether existing buildings needed a new roof (GSA 2011). The decision to install a green roof should consider the impact of work on user, occupants and tenants. The GSA analysis supported the general CBA finding that green roofs offer great potential savings and benefits. The specific real estate effect of green roofs, or their impact on real estate economics from a market and financial perspective, yields varying benefits that can affect a building's net operating income and market valuation (GSA 2011. Peck et al, 2009). A onetime valuation of this real estate effect is similar to the NPV of the actual benefits, whereas according to GSA (2013), the NPV of these ongoing savings and a greater building value are hard to realise. Furthermore the aspects considered in the community portion of the CBA are a part only of the actual impact of a green roof. If real estate value and the productivity of adjoining properties were included, the benefits would potentially far outweigh the costs (GSA 2011). Similarly, the value and productivity of the building itself could add to the already positive NPV. Finally they asset that market acceptance of green roofs and the value of the work occurring in the space are two areas that need to be better understood before they can be accounted for (GSA 2011).

AECOM (2017) provide a good example of the application of a more integrated assessment of the value generated from living architecture is the report Green Infrastructure: A vital step to Brilliant Australian cities. In their report they present analysis that the doubling the tree canopy at the Green Square development project in Sydney would result in a 'noticeable improvement in property value, health and wellbeing, suitability for walking, amenity, calming of traffic and other factors (p. 22). They highlight the relation between the number of trees and size of canopy, which drive both cost and benefits. We adapt their analyst in Figure 10 below.

In this section we reviewed the key ways in which living architecture drives value and presented a number of notable studies which attempt to quantify the value. In our final report from this project, we will present an integrated assessment for Sydney, which may be adapted for to other locations. The focus will be on devising a number of plausible trajectories for the development of a living architecture industry.

8. Conclusions and further study

In this section of the literature review, the conclusions for each section are presented and recommendations for areas of further research are identified.

There are a numerous drivers for the establishment of a living architecture (green roofs, walls and facades) in cities. As urban populations increase and cities become bigger, there is an increase in greenhouse gas emissions, air pollution, impervious surfaces urban temperatures and a loss of tree canopy cover and land for food production. Living architecture can help mitigate these issues. Green roofs, walls and facades have multiple social, economic, ecological, environmental, and public health benefits.

Barriers to the establishment of a living architecture include social, economic, technological and environmental barriers. Costs are a significant barrier, as well as a lack of experience in the industry, especially in terms of construction and management of green roofs, walls and facades. The capacity of the construction industry for green roofs is in a developing phase and not fully ready to roll out the green roof installation on a wider scale in buildings, precincts, and city scales. Further training and skill development is required to increase uptake. While there is significant potential to retrofit existing buildings, the feasibility of this is determined by the ability of the buildings to sustain the associated structural loads. There is also a lack of appropriate policy and regulations to integrate living architecture practices at the design phase of new buildings and also to retrofit existing buildings.

Resilience and resilient cities is a concept that will increase in importance in the coming decades. Action at the building level is vital and ultimately filters up to city, regional and national scales. For example retrofit of all structurally adequate roofs and walls in Sydney and Melbourne would lead to mitigation of the urban heat island, which will increasingly impact health and livability of our major cities. Similarly improvement in storm-water attenuation and decreases the impacts of flash flooding will occur as a result of mass green roof and wall retrofit. Resilience issues relating to Sydney Melbourne, Toronto, Singapore, London and Rotterdam are similar and can be mitigated through specification of living architecture such as green walls and roofs. Two resilience issues of heatwave and rainfall flooding can be alleviated through living architecture; questions arise as; to what extent is green roof and wall retrofit required to make a difference? Rainfall flooding is an issue also for Rotterdam, Singapore and Toronto, whilst heatwave affects Rotterdam and Singapore.

Our review of international policy across Singapore, London, Stockholm, Toronto and Rotterdam demonstrated a variety of approaches taken by policy makers in each of these cities. There is a mix of mandatory and voluntary policy mechanisms to increase installation of green roofs and walls. These cities have different drivers for the implementation of green roofs and walls, most often related to issues of increasing the resilience and livability of the city. Cities with more developed living architecture industries have a range of policy approaches to encourage and/or mandate green roofs and walls (Pianella et al. 2016). The approaches adopted in these cities are expanded and critiqued in the Case Study report accompanying this report.

There is no consistent policy approach to green roofs and walls across the different states of Australia. None of the states have a policy for green roofs and green walls, however the City of Sydney and City of Melbourne councils have created policies for each of their LGAs. NSW, Victoria, South Australia and Western Australia all have varying numbers of documents (including guidelines and policies) which make reference to green roofs and green walls. Overall there is a lack of policy to promote living architecture in Australia.

Mandatory or voluntary approaches are the key policy mechanisms for increasing the uptake of green roofs and green walls. There are four different types of policy instruments which can be utilised: information and advocacy; incentives; government demonstration and provision, and regulation. Mandatory approaches fall into the regulation category, while voluntary approaches can be information and advocacy, incentives, or government demonstration and provision. International case studies demonstrate a range of approaches, although our research reveals that there are more voluntary approaches in place than mandatory.

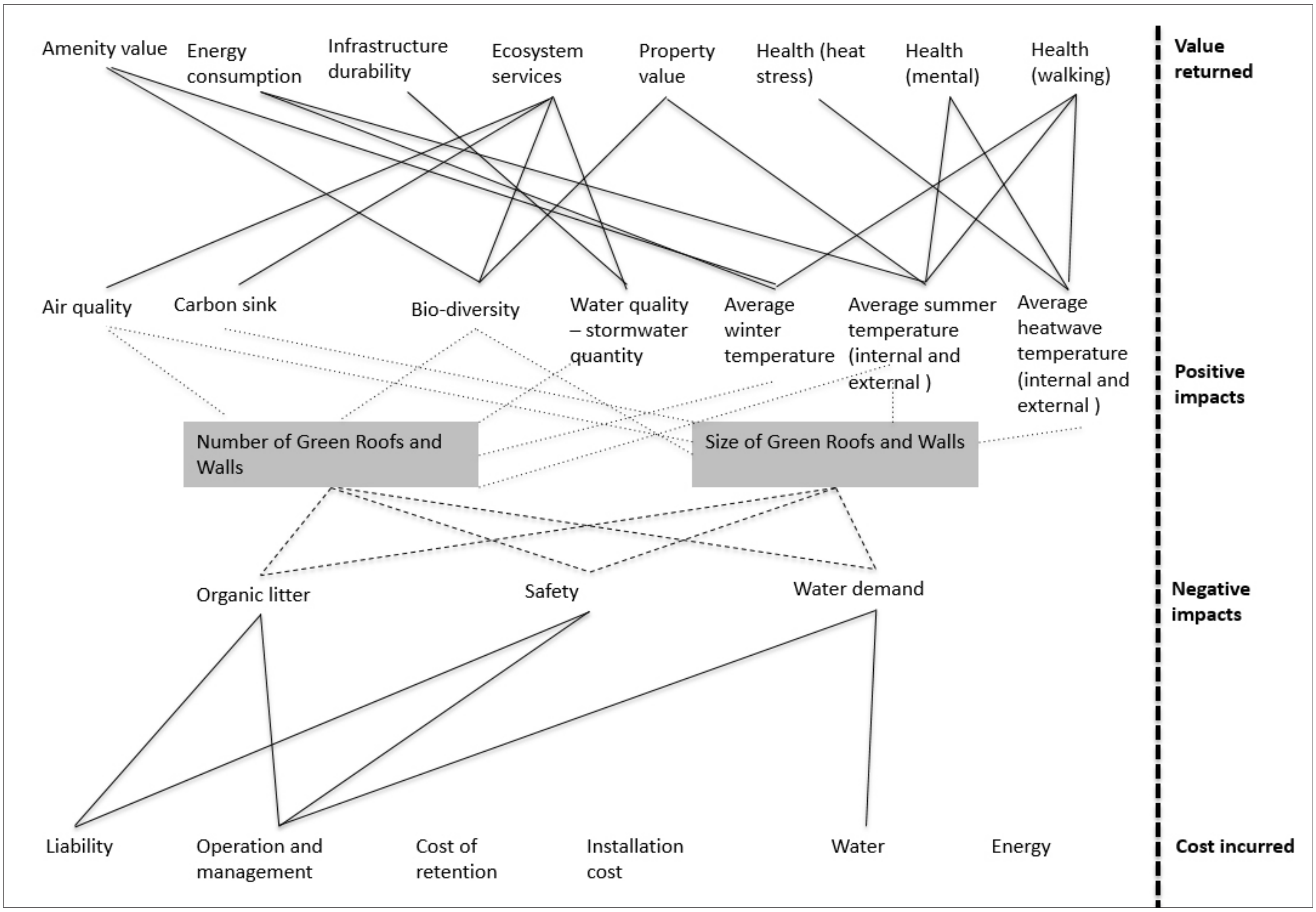
Cost Benefit Analysis undertaken in the US indicated a viable case for large-scale retrofit of green roofs. Evidence of increases in residential property value with more green infrastructure exists in Canada of between 6 and 15%, and it is recommended a study is undertaken to model the percentage of uplift in value in various Australian cities and suburbs. On a city scale, modelling in Toronto Canada showed the UHI could be attenuated by 0.5°C to 2°C through green roof retrofit. If green walls and living walls are added to this calculation reductions would be greater. Liveability of both Melbourne and Sydney will be affected by predicted temperature increases and we need to provide this empirical data for those cities.

The figure on the following page summarises diagrammatically the positive and negative impacts of living architecture in the form of green roofs and walls have in new build and retrofit. The diagram illustrates the value returned at individual level and at societal level. It shows the case for adoption of green infrastructure is compelling. The figure also illustrates the costs incurred in implementation of the measures. The questions which remain unanswered in Australia are; how much green infrastructure do we need to retrofit in order to achieve resilience? What is the cost benefit analysis for this? And what does the business case look like? Finally, is this more likely to be delivered through a market lead approach, a mandatory approach, or a hybrid of the two approaches? The final submission will present different scenarios and the modelling to demonstrate the case for mandatory or voluntary approaches and their respective strengths and weaknesses.

The recommendations for actions to promote the uptake of living architecture include the following actions.
1. Recommend the use of the RICS Best Practice Guidance Note on Green Roofs and Walls.
2. Articulate to clients the primary and co benefits of living architecture when briefing client on new build and retrofit options.
3. Offer traning and education opportunities to stakeholders in respect of new build and retrofit installation and maintenance.
4. Highlight to clients relevant issues relating to resilience, and its growing importance and the application of green infrastructure (green roofs and walls) as a way to alleviate heatwave and rainfall flooding issues and the benefits of future proofing developments.
5. Explore opportunities to adopt and adapt, where necessary, effective measures used internationally.
6. Lobby for a coherent national policy in respect of green roofs and walls in Australia.
7. Establish evidence of value uplift in property with green roofs and green walls - specifically the green roof and green wall contribution.

The recommendations include the following areas of further study are needed.
1. Model the percentage of uplift in residential and commercial property value in Melbourne and Sydney and various suburbs through various scenarios of low, medium and high levels of green roof and wall retrofit.
2. Model the reduction in UHI in Melbourne and Sydney and various suburbs through various scenarios of low, medium and high levels of green roof and wall retrofit.
3. Model the reduction in storm-water attenuation in Melbourne and Sydney and various suburbs through various scenarios of low, medium and high levels of green roof and wall retrofit.
4. Model the business case and CBA for adoption of green roofs and green walls based on a voluntary approach, a mandatory approach and a hybrid approach based on appropriate and transferable measures adopted internationally. Each approach to be modelled on weak and strong levels.

Figure 10 Relationship between costs and benefits of green roofs and walls



(source: authors)

9. References

ABCB, 2015, Climate zones in Australia. Retrieved on 6th April 2017 from http://www.abcb.gov.au/Resources/Tools-Calculators/Climate-Zone-Map-Australia-Wide

AECOM 2017. Green Infrastructure A vital step to brilliant Australian cities. http://www.aecom.com/content/wp-content/uploads/2017/04/Green-Infrastructure-vital-step-brilliant-Australian-cities.pdf.

American Society of Landscape Architects, 2002. Chicago City Hall Green Roof Chicago, Illinois. Retrieved on 13th May 2017 from https://www.asla.org/meetings/awards/awds02/chicagocityhall.html

Ansel, W. & Appl, R. 2009. *Green Roof Policies - an international review of current practices and future trends*. International Green Roof Association, Germany.

Australian Sustainable Built Environment Council (ASBEC). May 2016. LOW CARBON HIGH-PERFORMANCE. How Buildings Can Make A Major Contribution To Australia's Emissions And Productivity Goals. Full report. Retrieved from on 21st of August 2016 from: http://www.climateworksaustralia.org/sites/default/files/documents/publications/summary_report_-_low_carbon_high_performance_20160511_1.pdf

Baum, A., 2009. Quality, depreciation, and property performance. *Journal of Real Estate Research*.

Brown, P.J., 2016. Calculation of Environmentally Sustainable Residual Income (eSRI) from IFRS Financial Statements: An Extension of Richard (2012). In IFRS in a Global World (pp. 141-157). Springer International Publishing.

Bullen, P. A., 2007. Adaptive reuse and sustainability of commercial buildings. *Facilities*. 25: 20-31.

City of Chicago, 2017. Overview of the Green Permit Program. Retrieved on 13th May 2017 from https://www.cityofchicago.org/city/en/depts/bldgs/supp_info/overview_of_the_greenpermitprogram.html

City of London, 2016. Local Plan Monitoring Report – Green Roofs Local Plan Policy CS19: Open Spaces and Recreation. Retrieved on 11th February 2017 from: https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/development-and-population-information/Documents/local-plan-monitoring-paper-green-roofs-2016.pdf

City of London, 2014. Green Walls. Retrieved on 11th February 2017 from: https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/design/sustainable-design/Pages/green-walls.aspx

City of Portland, 2017, Ecoroof Incentive. Retrieved on 13th May 2017 from https://www.portlandoregon.gov/bes/48724

CSIRO and Bureau of Meteorology, 2016. Australia's Changing Climate. Australian Climate Change Science. Programme. Retrieved on 20th April 2017 from: https://www.climatechangeinaustralia.gov.au/media/ccia/2.1.6/cms_page_media/176/AUSTRALIAS_CHANGING_CLIMATE_1.pdf

City of Melbourne, n.d Unleashing the Potential of Nature: Discussion Paper on City Ecology, Ecosystems & Biodiversity. Retrieved on 13th May 2017 from https://participate.melbourne.vic.gov.au/download_file/1826/276

City of Sydney, 2017. The Green Roofs and Walls Perception-Study. Retrieved on 20th April 2017 from http://www.cityofsydney.nsw.gov.au/__data/assets/pdf_file/0008/127736/The-Green-Roofs-and-Walls-Perception-Study-Executive-Summary.pdf

City of Sydney, 2012. Green Roofs and Walls Strategy. Retrieved on 20th April 2017 from http://www.cityofsydney.nsw.gov.au/vision/towards-2030/sustainability/greening-the-city/green-roofs-and-walls

City of Toronto, 2017, Green Roofs, Retrieved on 20th February 2017 from http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=3a7a036318061410VgnVCM10000071d60f89RCRD

CanStar Blue. 2017. How much does air conditioning cost each month? Retrieved on 22nd April 2017 from: http://www.canstarblue.com.au/appliances/cooling-heating/air-conditioners/air-conditioning-running-costs/

City of Melbourne, 2013. Growing Green Guide, Retrieved on 23rd April 2017 from http://www.growinggreenguide.org/technical-guide/design-and-planning/cost/

Deep Green Landscaping, 2015, One40 William. Retrieved f1 May 2017 rom http://deepgreenlandscaping.com.au/green-roofs/one40-william-perth/

Department of Environment and Energy, 2013. Your Home: Australia's guide to environmentally sustainable homes, Commonwealth of Australia, Canberra.

Des Rosiers, F., The´riault, M., Kestens Y and Villeneuve, P., 2002. Landscaping and house values: an empirical investigation. *Journal Of Real Estate Research*, 23(1-2), pp.139-162.

Dixon, T and Wilkinson, S. 2016. Chapter 1: Building Resilience in Urban Settlements Through Green Roof Retrofit in 'Green Roof Retrofit: Building Urban Resilience' Eds. Wilkinson, S. and Dixon, T. Wiley-Blackwell.

Douglas, J., 2006. Building Adaptation Butterworth Heinemann.

Downton, P. 2013. Green roofs and walls. Your Home Manual. Retrieved on 5 May 2017 from: http://www.yourhome.gov.au/materials/green-roofs-and-walls

EC Harris, 2012. Office To Residential: Convert Or Redevelop? Final Report. Retrieved on 21 August 2016 from: http://www.echarris.com/residential

Eckstein, O., 1958. Water resource development-the economics of project evaluation. *Water resource development-the economics of project evaluation.*

Elkington, J., 1997. Cannibals with forks. *The triple bottom line of 21st century.*

Evans, S.and Pommer, C.2011, NPS Podium Roof Garden. Retrieved on 1 June 2015 from http://www.archello.com/en/project/nps-podium-roof-garden

Feitosa, C. G., and Wilkinson, S. 2016. Chapter 2: Technical and Engineering Issues in Green Roof Retrofit. in ‘Green Roof Retrofit: Building Urban Resilience’ Eds. Wilkinson, S. and Dixon, T. Wiley-Blackwell.

Fytogreen, 2016, Beare Park, Elizabeth Bay – Sydney. Retrieved on 14th May 2017 from http://fytogreen.com.au/beare-park-elizabeth-bay-sydney/

Fytogreen, 2016, Adelaide Zoo – Curved FytoWall & Roof Garden, Retrieved on 6th June 2017 from http://fytogreen.com.au/adelaide-zoo-curved-green-wall/

GovHK, 2016. Greening Hong Kong. Retrieved on 14th May 2017 from https://www.gov.hk/en/ residents/ environment/sustainable/greening.htm

GRaBS (Green and Blue Space Adaptation for Urban Areas and Eco Towns) 2017. GRaBS Expert Paper 6 the green space factor and the green points system. Retrieved on 17th April 2017 from http://www.xn--malm8qa.se/download/18.d8bc6b31373089f7d980008924/1491301018437/greenspacefactor_greenpoints_grabs.pdf

Greater London Authority, 2015. Film- Environmental infrastructure, Retrieved on 4th May 2017 from: https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/film-environmental-infrastructure

GSA. 2011. The Benefits and Challenges of Green Roofs on Public and Commercial Buildings. A Report of the United States General Services Administration. Retrieved on 4th May 2017 from: https://www.gsa.gov/portal/mediaId/158783/fileName/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.action

Hopkins, G. and Goodwin, C. 2011. *Living Architecture: Green roofs and walls*. CSIRO Publishing, Australia.

Hopkins, G. 2008, South Australian Government Incentive Program: Bushtops for Green Roofs and Walls. Retrieved on 14th May 2017 from: https://greenroofmembers.files.wordpress.com/2008/08/ graeme-hopkins-paper.doc

IGRA n.d. International Green Roof City Network Case Study Tokyo, Japan. Retrieved on 14th May 2017 from: http://www.igra-world.com/images/city_network/IGRN-Case-Study-Tokyo-IGRA.pdf

Kazmierczak, A. and Carter, J., 2010. Adaptation to climate change using green and blue infrastructure. A database of case studies.

Köhler, M. 2006. Long-Term Vegetation Research on Two Extensive Green Roofs in Berlin. *URBANhabitats*, Vol. 4(1), pp. 3-21.

Kincaid, D., 2003. *Adapting buildings for changing uses: guidelines for change of use refurbishment*. Routledge.

Kestens, Y., Thériault, M. and Des Rosiers, F., 2004. The impact of surrounding land use and vegetation on single-family house prices. Environment and Planning B: Planning and Design, 31(4), pp.539-567.

Klinkenborg, V. 2009. Up on the Roof. Retrieved on 4th May 2017 from: http://ngm.nationalgeographic.com/2009/05/green-roofs/klinkenborg-text

Lundberg, L. n.d. Augustenborg Botanical Roof Garden, Malmo. Retrieved on 1 May 2017 from: http://www.greenroofs.com

Maddison and Denniss, 2009. *An introduction to Australian public policy: theory and practice*, Cambridge University Press, Port Melbourne, Vic.

Mansfield, J. R., 2002. “What’s in a name? Complexities in the definition of ‘refurbishment’.” *Property Management* 20(1): 23-30.

Mazzali, U., Peron, F. and Scarpa, M., 2012. Thermo-physical performances of living walls via field measurements and numerical analysis. *WIT Transactions on Ecology and the Environment*, 165, pp.251-259.

Meerow, S, Newell, J.P. & Stults, M., 2016. Defining and resilience: a review. *Landscapes And Urban Planning*. 147 (2016) 38-49. http://dx.doi.org/10.1016/j.landurbplan.2015.11.011

Miller, M. J. 2014. A Farm Grows in Brooklyn—on the Roof. Retrieved on 26th April 2017 from: http://news.nationalgeographic.com/news/2014/04/140429-farming-rooftop-gardening-brooklyn-grange-vegetables-science-food/

Muldoon Smith, K. and Greenhaigh, P. 2016. Realigning The Built Environment. *RICS Building Surveying Journal*, July August 2016, pp16-18.

Ness, D. A. 2002. Accounting To The Effects Of Oversupply Of Commercial Property. Ph.D. Thesis University of South Australia, School Of Geo-Informatics, Planning And Building. Retrieved on 19 June 2016 from:

Ngan, G. 2004. Green Roof Policies: Tools for Encouraging Sustainable Design

NSW Government Planning and Environment. 2014. A plan for growing Sydney 2014. Retrieved from 21st of August 2016 from: http://www.planning.nsw.gov.au/Plans-for-Your-Area/Sydney/A-Plan-for-Growing-Sydney

NSW Department of Planning and Environment 2016, Draft Medium Density Design Guide. Sydney

NSW Department of Planning and Environment, 2015, Apartment Design Guide. Sydney

NSW Office of Environment and Heritage, 2015, Urban Green Cover in NSW Technical Guidelines. Sydney

Pearce, D., 1976. The limits of cost-benefit analysis as a guide to environmental policy. *Kyklos*, 29(1), pp.97-112.

Pearce, D., 1998. Cost benefit analysis and environmental policy. *Oxford review of economic policy*, 14(4), pp.84-100.

Peck, S. W. 2012. The Rise of Living Architecture. Greenroofs for Healthy cities, Canada.

Peck, S. W., Callaghan, C., Khan, M.E. & Bass, B. 1999. Greenbacks from green roofs: Forging a new industry in Canada. Canada Mortgage and Housing Corporation. Ottawa Canada.

Perini, K., Ottelé, M., Fraaij, A.L.A., Haas, E.M. and Raiteri, R., 2011. Vertical greening systems and the effect on airflow and temperature on the building envelope. *Building and Environment*, 46(11), pp.2287-2294.

Perini, K. & Rosasco, P., 2013. Cost-benefit Analysis for green facades and living wall systems. *Building & Environment*. 70 p110-121.

Pianella, A, Bush, J, Chen, Z, Williams, N, and Aye, L. 2016 Green Roofs in Australia: review of thermal performance and associated policy development in J. Zuo, L. Daniel, V. Soebarto (eds.), Fifty years later: Revisiting the role of architectural science in design and practice: 50th International Conference of the Architectural Science Association 2016, pp. 795-804. The Architectural Science Association and The University of Adelaide.

Population Reference Bureau, 2011. World Population Highlights 2007: Urbanization, Washington DC, Population Reference Bureau, USA.

Prest, A.R. and Turvey, R., 1965. Cost-benefit analysis: a survey. *The Economic Journal*, 75(300), pp.683-735.

Rambaud, A. and Richard, J., 2015. The "Triple Depreciation Line" instead of the "Triple Bottom Line": towards a genuine integrated reporting. *Critical Perspectives on Accounting*, 33, pp.92-116.

Resilient Design Institute. What is resilience? Retrieved on 20th of August 2016 from: http://www.resilientdesign.org/what-is-resilience/

RICS 2015. Our changing world: Lets be ready. Retrieved on 19th June 2016 from http://www.rics.org/au/knowledge/research/insights/futuresour-changing-world/

RICS, 2016. Office environments and productivity in the Middle East: Challenging preconceptions an understanding why one size does not fit all. Middle East Council for Offices MECO). Retrieved on 16 June 201 6from www.rics.org

RICS Best Practice Guidance Note on Green Roofs and Green Walls. 2015 Wilkinson, S.J., Goddard, J.G., Croft, L., Fisher, M., Willers, M., & Paul, M. Published RICS. April 2016. https://www.researchgate.net/publication/305725617_Professional_Practice_Guidance_Note?showFulltext=1&linkId=579d450508ae80bf6ea48763

Rural Industries Research Development Corporation, 2012, *Living Wall and Green Roof Plants for Australia*, Commonwealth of Australia, Canberra.

Sanchez, A. X., Osmond, P. & Van der Heijden, J. 2016. Are Some Forms Of Resilience More Sustainable Than Others? International high-performance built environment conference – a sustainable built environment conference 2016 series (SBE 16), iHBE 2016.

South Australian Department of Environment, Water and Natural Resources, 2013. Water sensitive urban design: Creating more liveable and water sensitive cities in South Australia

Sharifi, E., & Lehmann, S. 2015. 'Comparative Analysis of Surface Urban Heat Island Effect of Rooftops and Streetscapes in Central Sydney'. *Journal of Urban and Environmental Engineering* (JUEE), 9(1), pp. 3-11.

South Australia Department of Planning and Local Government, 2010. Technical Manual for water-sensitive urban design in Greater Adelaide

Steele, O. 2016, 88 Angel Street Newtown. Retrieved on 16 November 2016 from http://88angel.com.au/

Summers, M., & Simmons, R., 2009. Keeping Cool Survey: Air Conditioner Use by Australians with MS Public Policy Related Results & Recommendations. Retrieved on 22nd April 2017 from: https://www.cuac.org.au/research/external-research/179-keeping-cool-survey-air-conditioner-use-by-australians-with-ms/file

Sydney Morning Herald. 2008. Green roofs growing in popularity. Retrieved on 2nd May 2017 from: http://www.smh.com.au/news/environment/energy-smart/green-roofs-growing-in-popularity/2008/09/16/1221330837223.html

Thomsen, A. and Van der Flier, K., 2011. Understanding obsolescence: a conceptual model for buildings. *Building Research & Information*, 39(4), pp.352-362.

UN 2015. Sustainable Development Transforming our world: the 2030 Agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015. Retrieved on 21st of August from: https://sustainabledevelopment.un.org/post2015/summit

UN Department of Economic and Social Affairs (DESA) 2015, "World Population Prospects: The 2015 Revision'. Retrieved on 19th June 2016 from http://www.un.org/en/development/desa/news/population/2015-report.html

UN-Habitat. 2011. Cities and Climate Change: Global Report on Human Settlements 2011. London: United Nations Human Settlements Programme.

UN Populations Fund. World Population Trends. Retrieved on 19th June 2016 from http://www.unfpa.org/world-population-trends#sthash.oMfXUZJO.dpuf

University of Melbourne and IMAP. 2014. Growing Green Guide: A guide to green roofs, walls and facades for Australia. Retrieved on 5th May 2017 from: http://www.growinggreenguide.org/wp-content/uploads/2014/02/growing_green_guide_ebook_130214.pdf

Urban Green Council. 2013. Building Resilience Task Force Summary Report. June 2013 New York City. Retrieved on 21 August 2016 from: http://www.urbangreencouncil.org/content/projects/building-resiliency-task-force.

Urban Developer, 2016, Australia's First Breathing Green Wall Lifts Lendlease. Retreived on 9 August 2016 from https://www.theurbandeveloper.com/lendlease-barangaroo-junglefy-green-wall/

Urbis, 2007. Study on green roof application in Hong Kong. Retrieved on 14th May 2017 from https://www.archsd.gov.hk/media/11630/green_roof_study_final_report.pdf

Victoria Department of Environment, Land, Water & Planning, 2016. Better Apartment Design Standards, Victorian Government

Western Australian Department of Planning, 2016. Draft Apartment Design: Volume Two of State Planning Policy No. 7.3 Residential Design Codes: Guidance for multiple-dwelling and mixed-use developments, Western Australian Government

Wilkinson, S., 2011. The relationship between building adaptation and property attributes (No. Ph. D.). Deakin University. Retrieved on 21st August 2016 from; http://dro.deakin.edu.au/view/DU:30036710

Wilkinson, S. J. 2012. Conceptual understanding of sustainability in Australian Construction firms. CIB Montreal Canada June 2012. Conceptual understanding of sustainability in Australian Construction firms

Wilkinson, S.J., 2013. Conceptual understanding of sustainability in Australian property organisations. *Journal of Property Management*. ISSN 0263-7472. Vol. 31 No. 3. Pp 260-272. http://www.emeraldinsight.com/journals.htm?issn=0263-7472

Wilkinson, S. 2015. Conceptual Understanding Of Sustainability In Built Environment Professionals. Zero Energy Mass Custom Homes International Conference (ZEMCH) conference Lecce Italy 22-24th September 2015. ISBN: 978-88941-52609.

Wilkinson, S., Lamond, J., Proverbs, D.G, Sharman, L. Heller, A. Manion, J. 2015. Technical considerations in green roof retrofit for stormwater attenuation in the Central Business District, *Structural Survey*, Vol. 33 (1), pp.36-51.

Wood, S. n.d. Sydney's Central Park East tower ranked one of the world's best. Retrieved on 1 May 2017 from http://www.sbs.com.au/news/article/2014/05/20/sydneys-central-park-east-tower-ranked-one-worlds-best

World Bank Group. 2015. Building Regulation For Resilience. Managing Risks For Safer Cities. Retrieved on 21 August 2016 from: www.worldbank.org

Wuttke, A. n.d. Breathe Architecture. Retrieved on 1 September 2016 from http://www.breathe.com.au/the-commons-1/y06x89qorgl21jp2ayk8yikrrprz0m

100 Resilient Cities (2016) 100 Resilient Cities. Retrieved on 24th August 2016 from: Http://Www.100resilientcities.Org/Cities#/-_/

Musee du quai Branley, Paris (source: Ian, 2010)