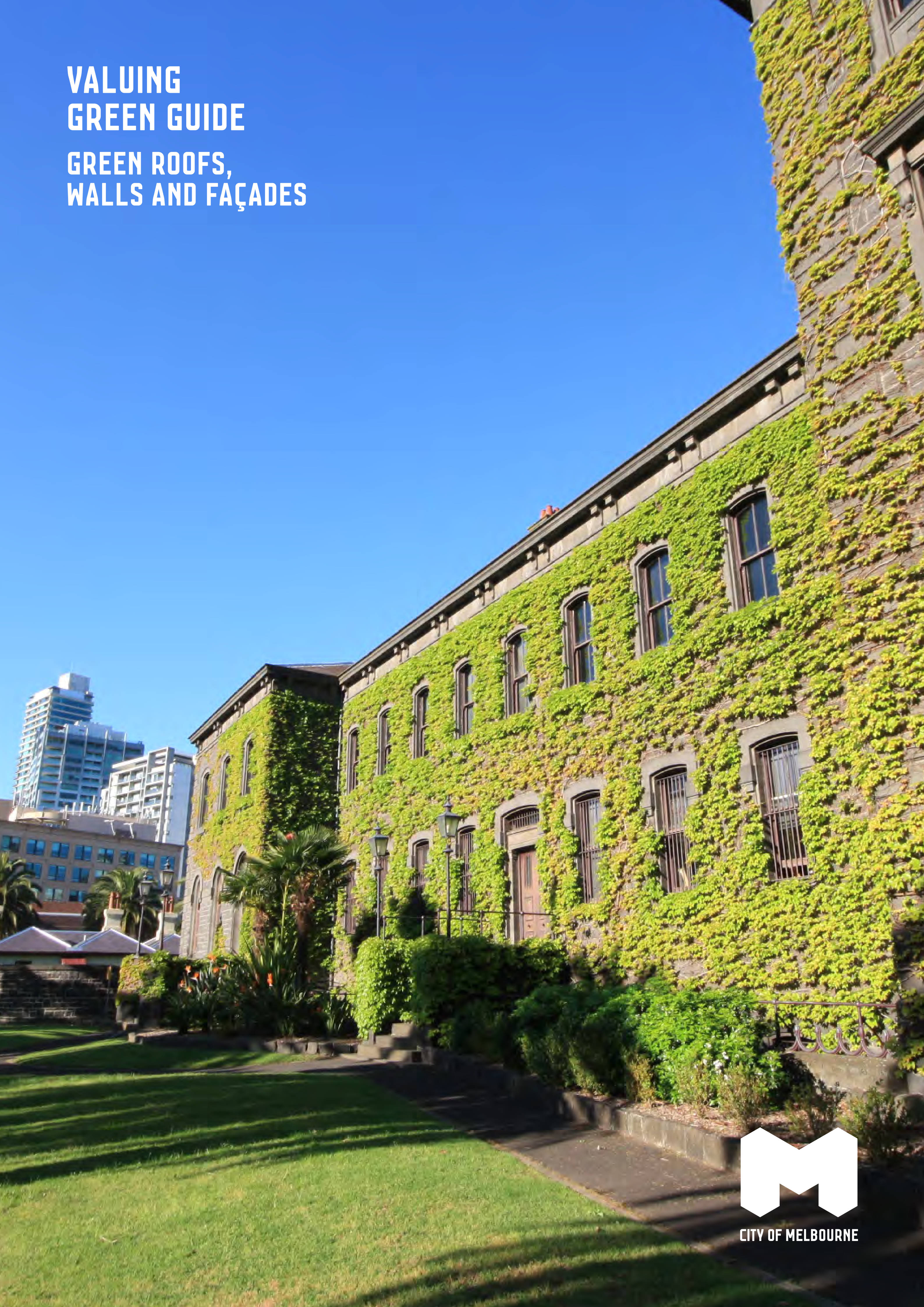
# VALUING GREEN GUIDE

## GREEN ROOFS, WALLS AND FAÇADES



CITY OF MELBOURNE

# A CITY THAT CARES FOR THE ENVIRONMENT

Environmental sustainability is the basis of all Future Melbourne goals. It requires current generations to choose how they meet their needs without compromising the ability of future generations to be able to do the same.

**Acknowledgement of Traditional Owners**

The City of Melbourne respectfully acknowledges the Traditional Owners of the land, the Boon Wurrung and Woiwurrung (Wurundjeri) people of the Kulin Nation and pays respect to their Elders, past and present.

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# FOREWORD FROM THE COUNCILLOR

When you value something, you protect it and care for it. For something as precious as our environment, we have to ask ourselves how much we value our wellbeing, our community, our biodiversity and the ecosystem we are creating for our future generations.

Surrounded by open and green spaces, Melbourne was once known as the heart of the Garden State. However, we are undergoing unprecedented growth and change. Our city is facing significant challenges with climate change, population growth and densification. These challenges are leading to impacts across our city as we move further away from natural landscapes to hard infrastructure.

Melbourne is renowned for its heatwaves and unpredictable weather. As we begin to feel the effects of population growth and climate change, our need for urban adaptability is more crucial than ever. Roofs in the City of Melbourne cover 880 hectares of our municipality, more than five times the size of Royal Park, the largest park in the area. By investing in urban greening projects and using these underutilised roofs, we can all help transform our city back into the green heart of Victoria.

The Valuing Green Guide, based on the work of Victoria University and the University of Melbourne, explores and summarises essential research into the value of green roofs, walls and façades in Melbourne.

Investments in green infrastructure are proven to provide smart, sensible and long-term solutions, assisting with flood mitigation, improving air quality and increasing biodiversity. The Valuing Green Guide shows that not only do green spaces benefit the health and wellbeing of people and improve our environment, but there are also economic benefits in protecting existing green spaces and developing new green infrastructure too. Research shows that green spaces lower energy costs and lead to increased profits and higher demand for real estate. We all want to work and live in environmentally friendly spaces, and the Valuing Green Guide demonstrates to property developers and owners the many benefits investing in green infrastructure on their buildings will contribute to a thriving, biodiverse future.

**Cr Cathy Oke**
Portfolio Chair, Environment

Figure 1. Roof garden at Kangan Institute, Melbourne.

# INTRODUCTION

Nature and cities don't always get on very well. Although nature is found throughout our cities, it is typically fenced off in parks and gardens, or lined up along roadsides. When green roofs, walls and façades are added onto buildings, nature jumps the fence and becomes part of the city's built infrastructure. And while these additions may not be entirely natural, they do provide many of nature's services. These services have a value, which can be estimated economically.

Whenever a building is erected, a set of small costs is created. The city gets a little hotter. Rainfall produces just that little more runoff, increasing the risk of flash flooding. There is more concrete and glass to look at – not high on the list of views that people prefer. There is less open space. People are that little less healthy.

For existing buildings, these social costs can be easily accepted as unavoidable. This doesn't have to be the case. Adding greenery to existing buildings can reverse these social costs to the public, while additionally providing private benefits to building owners and users.

While the initial recovery of installation costs by the building's owner is generally slower than usual commercial returns, green buildings are more likely to yield a capital gain than conventional buildings. Not only does the addition of greenery save energy and improve the look of infrastructure, but it also leads to greater property demand and increased real estate premiums.

Additionally, while construction is one of the most important sectors of the economy and a necessary part of expanding urban environments, we do not have to accept that this expansion of our urban spaces should come with hidden social costs on our environment and communities.

By understanding how green roofs, walls and façades can complement new and existing buildings and encouraging greater green infrastructure development, we can create a stream of public benefits for the community.

These are hard to value but eventually, many of these benefits will flow back into the economy. These are referred to as 'social returns'.

For the City of Melbourne, public benefits have been grouped into four important policy topics:

- Water, especially stormwater runoff and water quality.
- Temperature, especially the urban heat island and heatwaves.
- Biodiversity in the city.
- Human health and wellbeing.

This document is a summary of work by a team from Victoria University and the University of Melbourne who surveyed the economic benefits of green roofs, walls and façades in the research literature and industry reports[1]. Most places around the world where green roofs, walls and façades are common are either cool, temperate climates such as in Europe and North America, or moist tropical and subtropical climates like Singapore, Hong Kong and Osaka (Figure 2).

The big question is "how do those benefits transfer to a city with an increasingly variable climate like Melbourne?". Under climate change, the city has already become drier and hotter and is likely to become more so in future. Can green on grey infrastructure help make the city more liveable and make economic sense at the same time? While the survey considered both public and private benefits, the public benefits are mainly summarised here.

Figure 2. Namba Parks, Osaka, Japan. A nine-tier urban park with green gardens, roofs and walls over an office and shopping complex.

# GREEN ROOFS

Green roofs consist of plants in a growing medium on a roof. They are sealed at the base, and in drier climates are usually irrigated. Their vegetation ranges from grasses, succulents and herb meadows to small urban gardens and forests. For a full description, see the Growing Green Guide[2].

Green roofs are classified here as extensive, with a growing medium shallower than 200 mm, or intensive, deeper than 200 mm. Semi-intensive roofs, partway in between, have recently been added to international definitions. Extensive roofs are generally covered by succulents, grasses and other low growing plants. Intensive green roofs have taller vegetation grading up to shrubs and trees. Small roof gardens with plants in containers are not considered here, but intensive green roofs can have both beds and containers.

Intensive green roofs need stronger buildings to manage the weight of their infrastructure, vegetation and water. An issue for 'low cost' extensive roofs in climates like Melbourne's is whether they need access to irrigation. This adds to the cost, but ensures a constant supply of ecosystem services during drought periods when they may most be needed.

## Vertical greening

A green wall is like an extensive green roof turned on its side. Green walls can be relatively simple ranging from thick felt-like fabrics through to more complex media that support lush vegetation.

Green façades range from creepers directly attached to a wall, to plants on trellises with a gap between plants and wall. Green walls and façades have many different possible designs, so their performance in managing heat and other climatic stresses varies widely.

Their environments also differ widely. In Australia, walls on the north side of buildings have high exposure to sunlight and heat, and those on the south side are highly sheltered. Walls and roofs can be shaded by taller buildings, or in urban canyons. This variety makes it difficult to assess their overall economic performance.

## Potential

Roofs cover about 880 hectares or 23% of the total area of the City of Melbourne[3]. This is similar to total tree canopy cover (22% in 2014). There is significant potential for creating green roofs in Melbourne, with about 236 hectares of roof area having no or low constraints for intensive green roofs and 328 hectares for extensive green roofs. The overlap between intensive and extensive green roof suitability is over 90%. The target for Melbourne's urban forest is 40% by 2040[4]. If intensive green roofs were included in the urban forest target, fully realised they could make up to 18% of the total.

The potential extent of green walls and façades across the city has not been assessed. Many buildings will not be suitable because of heritage or design constraints such as large areas of glass, but thousands of square metres of vertical wall space will be suitable. Building turnover in the city is quite slow, with about 30 new buildings constructed each year. This creates a strong case for retrofitting existing buildings if wide-spread adoption is to occur. Expansive development of vacant land, such as Fisherman's Bend offer additional one-off opportunities.

**Figure 3. Triptych Apartments, Southbank.**

**Figure 4. Roden St, West Melbourne.**

# FROM ECOSYSTEM SERVICES TO ECONOMIC BENEFITS

Green infrastructure provides a wide range of ecosystem services. To be valued economically, their benefits need to be identified and assessed. These are defined by where each service is delivered, to whom and the type of value they receive (Figure 5).

A single service can provide a number of positive outcomes. For example, reducing the urban heat island effect can improve public health, save energy and extend infrastructure life, providing both public and private benefits to both individuals and the wider community. These advantages can be grouped according to financial, social and environmental criteria. For example, they may be represented by dollars, by measures of personal or community health and wellbeing, or by criteria for environmental health and biodiversity.

Social and environmental benefits make up 'social returns'. They also provide institutional values. The four policy topics of water, temperature, biodiversity, and health and wellbeing assessed here are important institutional values for the City of Melbourne.

Social returns and strong institutional values contribute indirectly to the economy. Public benefits may not result in direct income but do contribute to the economy over the longer term. Because these contributions are difficult to quantify, outcomes are often pursued by maximising non-monetary benefits as cost-efficiently as possible.

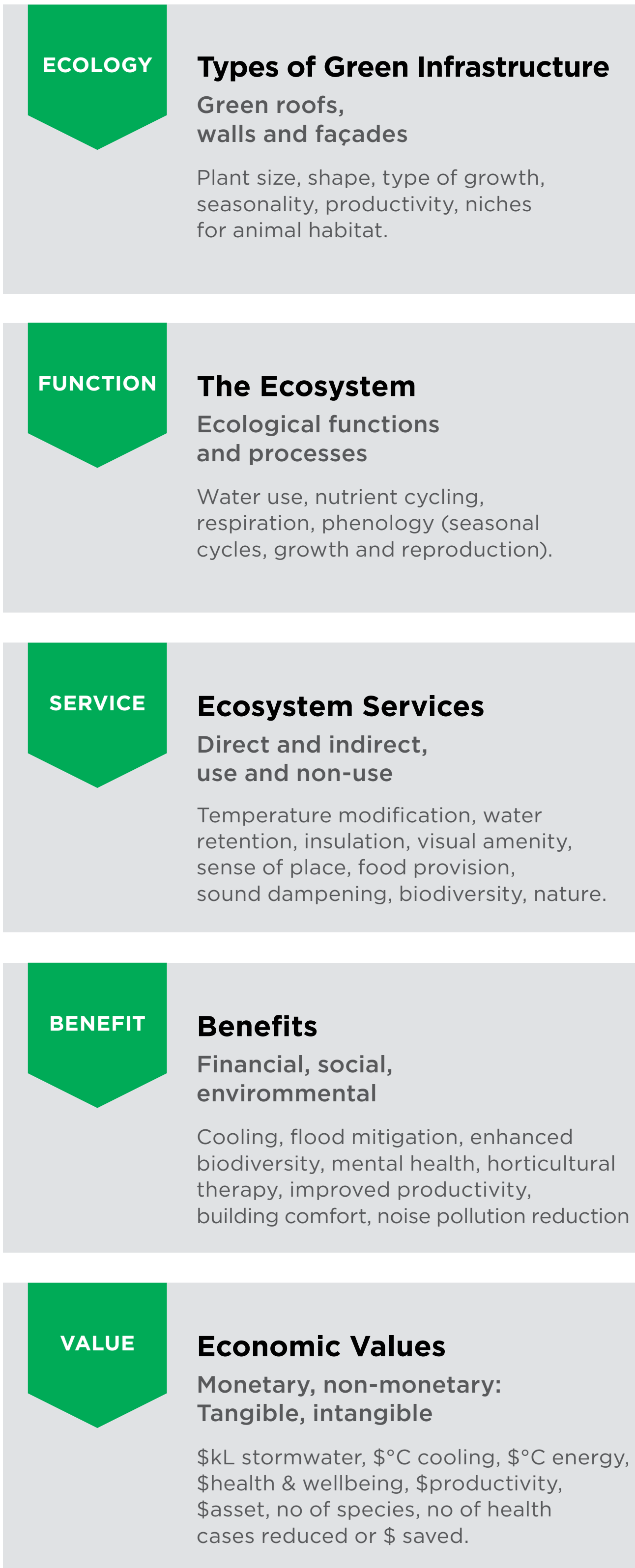


Figure 5. The pathways from ecosystem function and services to economic benefits and values[1,5].

| | INDIVIDUAL | COMMUNITY | INSTITUTIONAL |
|---|---|---|---|
| **Water** | • Increased flash flood safety | • Reduced flood cost and damage<br>• Improved water quality | • Flood safety/damage targets<br>• Water quality targets |
| **Temperature** | • Increased indoor comfort<br>• Energy use savings for building occupants | • Lower Urban Heat Island (UHI)<br>• Reduced air pollution production<br>• Improved street-level comfort and amenity | • UHI targets (4°C reduction goal) |
| **Biodiversity** | • Enjoyment of flora and fauna<br>• Visual amenity and status<br>• Personal and cultural environmental values | • Environmental education<br>• Citizen science | • Regional conservation targets and status<br>• Reduced climate impacts due to Green House Gas (GHG) reduction |
| **Health and wellbeing** | • Improved indoor comfort | • Reduced health costs<br>• Improved air quality<br>• Reduced sound pollution<br>• Increased walkability | • Improved levels of community health<br>• Reduced climate impacts due to GHG reduction |
| **Collective benefits** | • Higher property values<br>• Rooftop & courtyard locations for social and business activities | • Stronger neighbourhood identity<br>• Increases in productivity through visual amenity Increased economy through social returns | • Socially responsible investment<br>• City identity (community and government) |

Figure 6. Economic benefits delivered by green roofs, walls and façades, listed according to how they flow to individuals, communities or institutions.

Figure 7. Green roofs and raingardens dramatically reduce stormwater runoff.

Figure 8. The Chicago City Hall roof is famous for its contribution to reducing the city's UHI.

Figure 9. The Burnley Biodiversity Green Roof at The University of Melbourne.

Figure 10. Green roofs are becoming an important part of health facilities.

# WATER

Green roofs, walls and façades can be an important part of integrated urban water management, essential for improving future urban liveability and sustainability.

In built-up urban areas typical of inner Melbourne as much as 90% of rainfall can become runoff, compared to 20–30% for natural areas[6]. Hard surfaces produce rapid peak flow, increasing the risk of flash flooding. Stormwater in urban areas was once seen as a problem to be rid of quickly, but is now being seen as an untapped resource. Green roofs, walls and façades intercept rainfall, slowing runoff down and reducing peak flows. If this water is harvested, it can be used for irrigation, which helps keep the city cool. Well managed green infrastructure can also lead to improved water quality by intercepting pollutants and nutrients.

Green roofs can intercept most rainfall in Melbourne's climate where daily falls are generally low. A recent study estimated that a 100 mm deep extensive green roof in Melbourne can intercept between 86–92% of annual rainfall[7].

Green walls and façades will intercept some rainfall that would otherwise flow down the outside of buildings, especially in windy conditions, but this effect is generally not quantified. Volumes would be much smaller than those intercepted by green roofs.

## Climate change

Under climate change, the water cycle is becoming more intense, with longer dry periods punctuated by more intense heavy rainfall. Melbourne city's long-term rainfall was 660 mm, but in 1997, shifted downwards by 105 mm to 555 mm. Slightly more than half fell in May–October and slightly less in November–April, but this has now reversed. Rainfall intensity has increased for heavier falls, increasing the risk of flash-flooding.

One lesson learnt during the Millennium Drought (1997–2009, annual rainfall 507 mm) was that water conservation can have negative effects – urban trees need a regular water supply to remain healthy. A dry city is also a hot city. Unhealthy plants cannot produce many of the services needed including aesthetics, pollution removal and cooling. Melbourne's rainfall has not recovered following wetter years in 2010–11, averaging 562 mm. The shift to drier and warmer conditions after 1997 is ongoing. Hotter conditions are very likely and rainfall futures are uncertain.

While in many parts of the world extensive green roofs are rainfed, most green spaces still require irrigation support to thrive. While a 2013 study found that unirrigated green roofs in south-central Texas had some beneficial cooling[8] effect, one developer of energy-efficient commercial buildings in Vancouver, with its much wetter and cooler climate, told the project that unirrigated extensive roofs in that city had failed.

In order to ensure ecosystems thrive, it is crucial that research into water collection and supply, and healthy and appropriate plan species is completed. The provision of water, preferably collected locally, will be needed to sustain most green infrastructure on buildings. However, more research is needed to determine water supply needs for different types of roofs, walls and facades suitable for Melbourne's climate. Additionally, healthy vegetation is also vital for ongoing delivery of ecosystem services, but more research needs to be conducted into the selection of suitable flora species.

## Valuing water services

Aspects of water services that can be valued include:

- intercepted water used as an alternative water supply for irrigation.
- intercepted water reducing flood speed and peak flow.
- intercepted water preventing the flow of nutrients and pollutants into streams and the bay.

The source of irrigation water used on green infrastructure is important for both price and sustainability. Irrigation water can be sourced from drinking water, recycled water or harvested locally. Current retail costs for potable water are $2.49 per thousand litres (kL) up to 440 kL per day, rising to $2.93 for more than 440 kL per day. Non-residential recycled water supply is slightly cheaper at $2.21 per $kL[9].

Locally-harvested water can be costed according to the capital outlay in installing a water collection system as part of a green roof, wall or façade, converted into a price per kL over the lifetime of the project. The current value given by the City of Melbourne to stormwater interception is around the price of recycled water at $2.12 per kL. This figure was derived from international data and therefore needs to be updated with local estimates.

If water is collected onsite and the value of avoided flooding and captured pollutants exceeds the cost of irrigation, then there is a net benefit. The source of any energy used for irrigation supply also needs to be considered. If that energy is renewable, then only the cost of supply needs to be considered. If sourced from fossil fuels, the 'hidden' costs of greenhouse gas emissions would need to be added.

## Flood mitigation

The benefits of flood mitigation can be calculated in several ways:

- The fee for stormwater removal placed on new developments, which is derived from the capital and operating cost of providing stormwater systems, gives a value per kL.
- The benefit of reduced flood damages, estimated from flood modelling.
- Reductions in peak flow that delay capital works that would otherwise be needed to widen stormwater pipes.

These calculations can be quite complex. For the most accurate estimates, detailed modelling is needed on a catchment by catchment basis. For calculating flood damage, 'flood curves' that represent return periods from 1 year upwards have been calculated for Melbourne's subcatchments by Melbourne Water. Estimated annual damages from each subcatchment has been calculated, totalling $399 million per year in the Port Phillip region. Converting flood damage curves into volumes of water allows flood damage per thousand litres (kL) of water to be estimated.

Design guidelines that provide an average or 'standard' amount water retention in litre per square metre of intensive and extensive green roof per year would allow the economic benefits of flood mitigation to be estimated. Green roofs have been identified as a key water management option for the Elizabeth Street catchment (Figure 11). Currently, when modelling rainfall interception by trees, City of Melbourne uses a value of $2.12 per kL of water. Detailed flood studies that follow through to damage costs are likely to show a higher value.

## Water quality

For water quality, Melbourne Water values the removal of nitrogen at $6,645 per kilogram. Values for phosphorus and pollutants such as heavy metals are currently not being estimated. If a green roof or wall system has a closed water cycle and runoff is not flowing into streams, there will be a net water quality benefit. Based on the range of deposition rates estimated for Port Phillip Bay, nitrogen interception by a green roof could be valued within the range of $2.75 to $4.48 per $m^2$ per year.

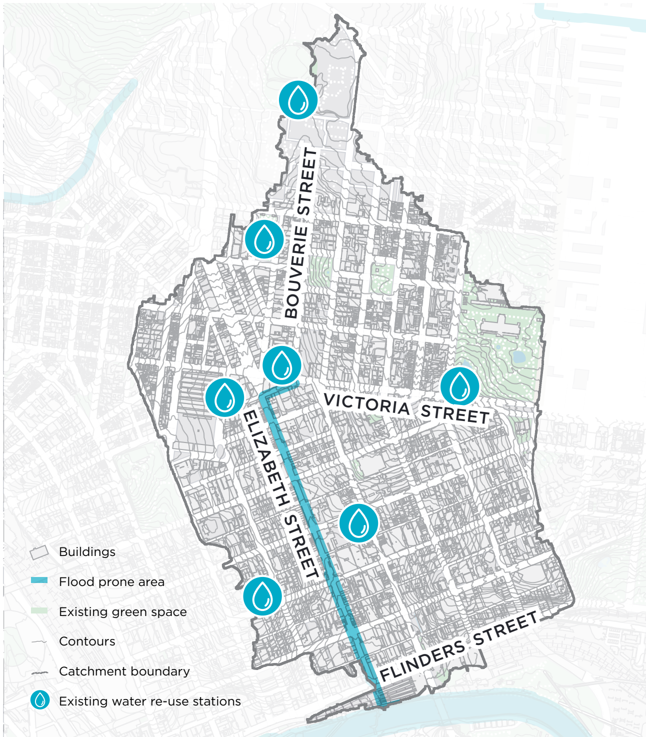


Figure 11. The Elizabeth Street catchment strategy incorporates green roofs that play an important role in flood control.[10]

Figure 12. Artistic rendition of the new Parliament House extension, Melbourne.

# TEMPERATURE

Green roofs, walls and façades modify temperatures in the following ways:

- By insulating and shading the building they are on.
- By cooling the air close to the building giving a local cooling effect.
- By adding to other vegetation in the city, they help to reduce the urban heat island effect.
- If reduced heating and cooling needs limits the use of fossil fuels, global warming will also be reduced, delivering global benefits.

These three scales of benefit – building, city-wide and global can be divided into public and private benefits (Figure 5). Public advantages go to communities, or to public bodies such as local or state government that represent the community, while private advantages go to individuals and businesses.

Benefits of temperature-related ecosystem services at the building scale are easiest to value.

## Direct insulating benefits

Extensive green roofs provide better insulation in summer for cooling but are not so good in winter, where the thinner, moist layer can emit heat. Intensive green roofs are more effective at offering year-round savings. The benefits are greatest on older buildings with poor insulation. Adding greenery to new buildings with high energy star ratings that are also well-insulated internally will not result in great energy savings, but will contribute to the overall energy rating.

Multi-storey buildings can save up to 5% on annual heat and cooling benefits, mainly on the upper floor(s). For individual houses and single-story commercial buildings, the savings can be higher, up to around 25% to 35% of energy use in some studies, the latter estimate from a hot-humid climate[1]. For mid level buildings such as shopping centres, savings will fall between these limits.

Retail customers collectively save more per unit area of green roof than single owners/tenants because they pay retail rather than wholesale energy prices. Gas usage is higher in apartments than offices due to after-hours heating in winter.

Similar energy savings have been modelled and measured for green walls and façades in Mediterranean climates. The main benefits are for summer interior cooling but they may also retain some heat in cold weather. Placing vegetation adjacent to or covering air conditioning intakes can also reduce cooling loads. More work is needed before estimates of economic benefits of walls and façades can be made for specific building types.

### Ecosystem services

| WHO BENEFITS? | | **LOCAL COOLING** | **URBAN COOLING** URBAN HEAT ISLAND | **REDUCED GLOBAL WARMING** |
|---|---|---|---|---|
| | **PUBLIC** | • Direct energy savings (public buildings)<br>• Local cooling (shade) on publicly accessible rooftops, courtyards<br>• Local cooling adjacent to green walls and façades<br>• Improved interior comfort (passive energy in public buildings) | • Cooler city (canopy effects) increasing comfort levels<br>• Improved walkability<br>• Increased comfort – reduced heat stress (direct health outcomes) | • Reduction in building energy use reduces $CO^2$ emissions (reduced climate impacts)<br>• Carbon sequestered (slight eductions in climate impacts) |
| | **PRIVATE** | • Direct energy savings (private buildings)<br>• Improved interior comfort (passive energy systems)<br>• Local cooling (shade) on privately accessible rooftops, courtyards | • Indirect energy savings (private buildings)<br>• Improved comfort levels (productivity gains for business) | • Net global economic benefits (very small) |
| | | **BUILDING** | **CITY-WIDE** | **GLOBAL** |
| | | | **WHERE IS THE BENEFIT?** | |

Figure 13. Temperature-related ecosystem services, scales of benefit and public/private benefits delivered by green roofs, walls and façades.

## City-wide (UHI) benefits

Along with cooling from urban forests and parklands, green roofs, walls and façades assist with urban heat island (UHI) cooling, through transpiration. The potential area suitable for green roofs is similar to the area covered by the existing urban forest. Green roofs could become an important part of Melbourne's urban forest strategy, which aims to reduce the UHI by up to 4°C[4]. The UHI effect is greater at night. Cooler nights will delay warming during the day, slowing and reducing the afternoon peak.

The vertical canopy on green walls provide efficient cooling for a small horizontal footprint. Extensive green walls and façades will add substantial extra canopy to the urban forest, but this has not as yet been modelled at the city scale. Green walls in urban canyons can result in energy savings exceeding 50%, contributing to annual savings of up to 10%.

Green walls and façades on the north-facing sides of buildings will produce the greatest benefit, but the systems and species most suited to high-exposure areas still need to be determined. The potential is significant, but largely untested.

Widespread temperature-related benefits include improved indoor and outdoor comfort levels and reduced energy consumption. Improved health and higher productivity are two indirect benefits. All are difficult to quantify because they hard to estimate and produce small but widespread effects.

Figure 14. Triptych Apartments, Southbank.

## Global benefits

Greenhouse gases in the atmosphere can be managed in two ways:

1. By reducing the emissions of greenhouses due to lowered heating and cooling needs at the building and city scale.
2. By sequestering carbon in vegetation, intercepting black carbon particles and absorbing greenhouse gases, such as nitrous oxides.

For heating and cooling, the benefits of reducing greenhouse gas emissions will only be realised if power is sourced from the grid. If buildings are serviced directly by renewables, then this benefit has already been received.

Global benefits of reduced levels of climate change are measured either according to the direct market or shadow price of $CO_2$-equivalent carbon or due to the social cost of carbon. The former is set through regulation or is a market price tied to the cost of abatement. The latter is an estimate of future damages produced by one tonne of $CO_2$ emitted. The social cost of carbon is the more realistic measure of global benefits of reduced warming.

For Victoria, each kiloWatt hour (kWh) of energy used from mains electricity releases 1.08 kg of $CO_2$- equivalent greenhouse gases[11]. Renewable energy generation is bringing this ratio down, but electricity generation from brown coal keeps it high. For gas, the amount released per kWh is 0.54 kg $CO_2$-e.

Based on social cost of carbon applied in the USA by the Obama administration[12], global damages per ton of $CO_2$ in 2015 were, in 2017 dollars, A$11 per ton (5% annual discount rate), A$61 (3% discount rate) and A$94 (2.5% discount rate). There is good evidence that these costs are underestimated.

Lifecycle GHG emissions are calculated as the difference between those used in manufacture and installation and those saved. The cost of installing and operating a green roof, wall and façade as a product of embedded greenhouse gases provides an estimate of the cost of abatement.

Sequestration of stored carbon is a one-off benefit when full potential is reached, which is small except for intensive green roofs. The greenhouse benefits of air pollution reduction have not yet been quantified for levels expected to occur in Melbourne. Because much of the pollution comes from traffic, it varies highly over space and time within built-up areas.

# BIODIVERSITY

Green roofs, walls and façades are highly artificial environments. Because they are designed to maintain the structural integrity of the buildings they grow on, they have limited resources for vegetation to thrive. For example, many of the small plants that grow around Melbourne are deep-rooted to cope with the sometimes harsh natural conditions. However, they also present an opportunity to increase urban biodiversity that would otherwise not be available.

Urban biodiversity can be a major feature of green roofs, walls and façades, by design and through chance. This includes the choice of plant species used and the provision of habitat, both natural and artificial. Natural habitat is provided by plants structure and resources, but artificial habitat can create niches for fauna. For example, bee hotels will attract native bees that live on grassland herbs and small shrubs. Because little is known about how biodiversity can perform in Australian urban settings, ongoing monitoring is important.

Although local species are adapted to Melbourne's climate, our knowledge of which will be most successful on and around buildings, especially on walls and façades is limited. For exotic species, we can draw on international experience in similar climates. The buildings themselves provide a range of microclimates that range from north-facing exposed sites, to low light and south-facing sites that are highly sheltered. This also allows for a wide selection of species and micro-habitats.

Many rarer plants from the Melbourne region can be grown in artificial but biodiverse assemblages, creating rooftop meadows similar to those in Europe, where they form part of the identity of a place. One advantage is that predation from pests like rabbits will be limited, presenting conservation opportunities for palatable and rare species. Hardy monocultures, such as succulents are often used in extensive roofs, but people tend to prefer biodiverse and attractive plant combinations.

The small, fragmented patches provided by individual green roofs, walls and façades present a challenge for maintaining ecological health. But as coverage expands, improved connectivity can open up opportunities for other plants and animals. Highly mobile fauna species, such as insects and birds, will take advantage of this. However, weeds and pests can also spread, so may need to be controlled. While resources can limit successful breeding for birds and insects – this can be counteracted by increasing ecological diversity and coverage.

## Services and valuation

Services provided by biodiversity include species conservation, cultural services, visual amenity, educational opportunities, and contributions to health and wellbeing. Benefits include improved cultural and conservation values, improved health and wellbeing (see below), community identity and potentially increased productivity from a more visually diverse landscape. These benefits are difficult to value, but evidence is being gathered across all of these areas.

The main methods used to value biodiversity economically are willingness to pay and shadow pricing (valuing a 'free' benefit at the same rate as a similar commercial activity). Developers around Melbourne who provide green infrastructure within new or retrofitted buildings claim they are able to charge a premium in price for purchase and rental. Once green infrastructure becomes more visible around Melbourne, people's preferences for these benefits will become more apparent.

Figure 16. Native bee hotel.

Figure 17. The Burnley Biodiversity Green Roof at The University of Melbourne.

Figure 15. Previous page shows the Burnley Biodiversity Green Roof at The University of Melbourne.

# HEALTH AND WELLBEING

The main benefits for health and wellbeing are:

- Reduced heat stress and improved comfort at building, street and city scale. Reduced cold stress within buildings.
- Benefits from seeing and being in green places (visual and physical amenity).
- Social connectivity through public places, such as rooftop gardens
- Improved recovery rates from passive and active horticultural therapy conducted in and around medical facilities.
- Reduced air pollution due to interception of a variety of pollutants.
- Reduced sound pollution, especially from green walls and façades.

## Health benefits

The main health benefit of temperature modification is reduced heat stress at building, street and city scales. Health impacts are greatest in poorly-insulated residences and on vulnerable people, especially those with pre-existing health conditions, the elderly and the homeless. Health benefits due to improved comfort levels need to be estimated from population characteristics and health outcomes for the Greater Melbourne region to be statistically valid. These results can then be scaled down to individual local government areas.

Cool season mortality and disease impacts outweigh those in summer – green infrastructure such as intensive roofs and green walls and façades, can provide some indoor benefits during colder weather. If changing the UHI, average outdoor winter temperatures will be slightly cooler, but the coldest extremes will be slightly warmer.

People in hospital with illness or injury recover faster if they have a view of greenness compared to concrete or brick, especially if they have access to green open space. This will reduce health costs and allow greater numbers of people to be treated. Green infrastructure is now being seen as an essential component of the modern health care facility, and is incorporated into the Victorian Comprehensive Cancer Centre (Figure 18) and the Royal Children's Hospital.

## Pollution reduction

Vegetation captures pollutant particles through direct deposition, as part of the respiratory process and can also utilise some as fertiliser (e.g., nitrogen species). It may also produce some pollutants such as volatile organic carbon, so there is a balance, mostly towards net take up.

The greatest value for health is produced by reductions in PM2.5, which is mainly produced by vehicles and other forms of combustion. PM10, ozone ($O_3$), $NO_2$ and $SO_2$ all contribute to respiratory conditions, even if within health limits.

Benefits are usually modelled. One study on an industrial site affecting 17,000 people in Melbourne's west estimated the following for tree canopy. PM10 health and welfare benefits ranged from $0.16 to $0.86 per $m^2$ per year. For PM2.5, direct health benefits were $0.35 to $2.89 per year[13]. The PM2.5 levels of capture were what would be expected close to major traffic routes. Intensive green roofs and walls would be expected to capture half to most of the amount intercepted by trees and extensive green roofs and façades about one-third to one-half. Valuing the capture of other pollutants would increase these benefits.

## Wellbeing and productivity

An emerging benefit of vegetation in buildings in urban areas is sound reduction. Attaching softer roofs and walls to buildings can reduce sound echoing from hard surfaces and also dampen sound within the building covered by vegetation.

Research on productivity at the national scale suggests that productivity losses due to heat in 2013/14 equalled 0.33% to 0.47% of GDP and for Victoria self-reported losses were $877 per person per year[14]. Multiplying that by Melbourne's Gross Regional Product of $92.12 billion estimates a range of $304 to $433 million. The per person losses multiplied by the workforce of 455,753 equals total losses of $403 million.

Even marginal gains to productivity through visual amenity and reduced heat stress could be substantial, running into millions of dollars each year. By reducing the experience of night-time heat stress and creating a cooler city environment, the majority of Melbourne's employees who live outside the city would benefit from relief outdoors and reduced stress levels, as they come to work.

Figure 18. The Victorian Comprehensive Cancer Centre has incorporated green infrastructure as part of evidence-based design to help improve the health and wellbeing of patients and staff.

# COLLECTIVE BENEFITS

Some benefits are not provided by specific ecosystem services but by green infrastructure as an asset. Many structures will be private assets but some aspects may serve as community assets, particularly if roofs have public access, are part of the city view or are sited on public buildings.

## Property benefits

In a US 2012 government study, rent premiums for commercial buildings with green roofs were 5.7% nationally and 7.4% in Washington DC. After factoring in the cost of green roofs, premiums were 2.5% and 3.3%, respectively. Real estate market valuation figures from survey data were US$140 $m^2$ of green roofs nationally and US$108 $m^2$ in Washington DC[15]. Other valuations based on a range of methods suggested up to 4% for green walls and 6% to 20% for green roofs, mainly on smaller apartment buildings, houses and offices[1].

Hotels will charge a premium for garden, atrium and park views. Office buildings that overlook parks also receive a premium in price and rents, to the point where they will sometimes purchase air space to prevent a view being built out. Widespread adoption of green roofs, walls and façades will result in improved views from a range of vantages within the city. These will increase the asset values of the buildings they are attached to and those who have improved views.

## Community benefits

Community scale benefits of many individual services can be aggregated up to community scale but there is also a set of benefits where the community is the direct recipient, rather than being an aggregation of individuals.
These include:

- Stronger neighbourhood identity.
- Educational facilities (Figure 19) Greenwich Village.
- Improved productivity and connectivity within the community, benefiting both public and private enterprises.
- Increased visitation and greater popularity of public spaces, and private spaces, such as new green roofs, where public access is granted.
- Increased social returns.

For community scale benefits to be realised, green roofs, walls and façades need to be rolled out at scale, so that broad areas of suitable roofs and walls are taken up. This is also required to deliver effective outcomes on flood control and the UHI. Community benefits such as neighbourhood identity are being traced through community surveys on an ongoing basis. Measures of innovation and community resilience can also assess change, but it will not be possible to separate the impact of green infrastructure on buildings from similar improvements in open space and community programs.

## Institutional benefits

Institutional benefits are gained through the successful rollout of policies and programs. Broadly, beneficiaries include levels of government, especially local, the community and business and industry. Strong institutions are essential for successful urban governance particularly with strong drivers of change, such as society and technology and changing risks, such as climate extremes.

For the City of Melbourne, key public policy areas relating to green infrastructure include the four areas concentrated on in this report, along with a focus on neighbourhoods and community feedback. Tourism, the arts and a place to conduct business are high on the public and private agenda, incorporating resilience and liveability.

State government also plays a role through sponsorship of green roofs programs, public health, water quality and management and infrastructure planning. Industry and business are invested in liveability, because this attracts talent, corporate social responsibility and returns on investment. The community has made it clear that they want local connections, investment in the environment and jobs. These are all benefits that may not be found as part of a cost benefit analysis but are an essential part of achieving long-term sustainability.

Figure 19. Greenwich Village Elementary School in New York has a 830 $m^2$ green roof that is an educational resource for its students.

# QUANTIFYING THE BENEFITS

Most of the individual benefits of green roofs, walls and façades can be provided more efficiently purpose-built measures. For example, air conditioning costs can be reduced by white roofs more cheaply than green roofs. However, conventional infrastructure cannot provide the full range of benefits obtained from green infrastructure. Local data is needed for reliable estimates. If data is unavailable, benefit transfer from similar settings elsewhere can be applied. Although green roofs are common in cool-temperate climates, especially in Europe, their adoption in hotter and drier climates similar to Melbourne's has been slower. Suitable examples are limited.

## Case study examples

Using simple transfer relationships from other parts of the world we have quantified the benefits of green roofs for two case studies: an office block and apartment building both built before 1980, so they are poorly insulated. Benefits covered are stormwater interception, water quality, energy savings for electricity and gas, and avoided climate damages.

Further savings not accounted for include extended roof life, health and water quality benefits of pollution reduction, carbon sequestration, increased building value, reduction of the UHI on energy demand and increased health and wellbeing including productivity.

Building 1 is a mid size office building and is assessed as (1) a single owner-occupier and (2) as a multi-tenanted building. Building 2 is an apartment building of similar size with multiple tenants who purchase retail energy.

Two types of roof are simulated: An extensive roof of grasses and herbs and an intensive roof covered by large shrubs and small trees. Both roofs are irrigated and 250 $m^2$ in area.

Two sets of value are assessed: current value in benefits per square metre and total value over a green roof life of 40 years. Two discount rates are used: a social discount rate of 2.5% for water and climate benefits, which is low by Australian standards but not internationally, and 7% for energy savings.

## Stormwater interception

The stormwater case study is based on current rainfall of 555 mm per annum continuing. This assumes that drought conditions since 1997/98 persist.

- The extensive green roof has an interception rate of 70%, or 398 mm per year.
- The intensive green roof an interception rate of 90%, or 500 mm pa.
- Water is priced as $2.12 per kL.

## Water quality

Based on the range of deposition rates estimated for Port Phillip Bay, annual nitrogen deposition is estimated at between 0.41 and 0.67 grams per square metre. The value of interception is based on nitrogen being priced at $6,645 per kg.

## Energy savings

A Northern American green roof energy calculator tuned to Sacramento's climate, similar to Melbourne's, was used to estimate energy benefits for the case study extensive and intensive green roofs[16]. Electricity and gas usage were priced at wholesale rates for the single occupier and retail rates for multiple occupiers.

## Avoided climate damages

Energy savings can be converted into GHG emissions and from there avoided climate damages. For Victoria, each kiloWatt hour (kWh) of energy used from mains electricity releases 1.08 kg of $CO_{2}$-GHGs and gas releases 0.54 kg $CO_2$-e. The social cost of carbon used is A$94 (2.5% discount rate).


Figure 20. Medibank building, Melbourne.

## STORMWATER

Extensive green roof intercepts 70% of rainfall
Intensive green roof intercepts 90% of rainfall

| Annual benefits per square metre | |
|---|---|
| • Extensive green roof | $0.82 |
| • Intensive green roof | $1.06 |
| **Lifetime benefits** | |
| • Extensive green roof | $21.10 |
| • Intensive green roof | $27.27 |

Figure 21. William A. Jones III building, Joint Base Andrews, Maryland, USA can reduce runoff by 65% and cool roof by 35–40%.

## WATER QUALITY – NITROGEN REMOVAL

| Annual benefits per square metre | |
|---|---|
| • Low estimate | $2.75 |
| • High estimate | $4.48 |
| **Lifetime benefits** | |
| • Extensive green roof | $70.87 |
| • Intensive green roof | $115.17 |

Figure 22. Biodiverse extensive green roof at Lydd Road, Camber, UK.

## ENERGY SAVINGS

| Annual benefits per square metre | |
|---|---|
| **Office building sole occupant** | |
| • Extensive green roof | $1.03 |
| • Intensive green roof | $1.40 |
| **Office building multiple occupants** | |
| • Extensive green roof | $2.75 |
| • Intensive green roof | $3.72 |
| **Apartment building** | |
| • Extensive green roof | $2.71 |
| • Intensive green roof | $3.25 |
| **Lifetime benefits** | |
| **Office building sole occupant** | |
| • Extensive green roof | $14.69 |
| • Intensive green roof | $19.92 |
| **Office building multiple occupants** | |
| • Extensive green roof | $39.22 |
| • Intensive green roof | $53.08 |
| **Apartment building** | |
| • Extensive green roof | $38.70 |
| • Intensive green roof | $46.41 |

Figure 23. State of the art green skyscraper, Bosco Verticale, Milan.

| CLIMATE DAMAGES | |
|---|---|
| **Annual benefits per square metre** | |
| **Office building sole occupant** | |
| • Extensive green roof | **$0.99** |
| • Intensive green roof | **$1.31** |
| **Apartment building** | |
| • Extensive green roof | **$1.63** |
| • Intensive green roof | **$1.77** |
| **Lifetime benefits** | |
| **Office building sole occupant** | |
| • Extensive green roof | **$25.48** |
| • Intensive green roof | **$33.76** |
| **Apartment building** | |
| • Extensive green roof | **$41.88** |
| • Intensive green roof | **$45.46** |

Figure 24. Plant and bird habitat, Kingsland Center, Brooklyn, New York.
Figure 25. Green roof and gardens, Vancouver, Canada.
Figure 26. The Venny, a green roof on a Kensington play space for young people.

| SUMMARY | |
|---|---|
| **Annual benefits per square metre** | |
| **Office building sole occupant** | |
| • Extensive green roof | **$5.59** |
| • Intensive green roof | **$8.24** |
| **Office building multiple occupants** | |
| • Extensive green roof | **$7.31** |
| • Intensive green roof | **$10.57** |
| **Apartment building** | |
| • Extensive green roof | **$7.92** |
| • Intensive green roof | **$10.56** |
| **Lifetime benefits** | |
| **Office building sole occupant** | |
| • Extensive green roof | **$132.14** |
| • Intensive green roof | **$196.12** |
| **Office building multiple occupants** | |
| • Extensive green roof | **$156.67** |
| • Intensive green roof | **$229.28** |
| **Apartment building** | |
| • Extensive green roof | **$172.56** |
| • Intensive green roof | **$234.32** |

| SELECTED OTHER BENEFITS (UNCOSTED) | |
|---|---|
| **Roofs** | |
| • Property values (houses & apartments) | 7–20% |
| • Commercial buildings (US national av.) | 5.7% |
| **Walls and façades** | |
| • Property values (dwellings) | 1.4–3.9% |
| • Sound reduction (10€–25€/$16–$40 per dB per hh) | 5–15 dB |
| **All** | |
| • Hospital recovery times (view, I study) | 8% |
| • Aesthetic benefits | needs local data |
| • UHI energy benefits | needs local data |
| • Health benefits (heat stress) | needs local data |
| • Visual amenity | needs local data |
| • Pollution (PM10 and PM2.5, W of Melbourne) | $0.51–$3.75 |

## Total benefits

Nitrogen interception and energy savings have the highest benefits, one social and the other a monetary benefit for building occupants. Stormwater and greenhouse gas mitigation are both public benefits and vary around $1 to $2 per square metres of green roof. Annual benefits, depending largely on the price of power and performance of extensive and intensive green roofs, range from about $5.60 to $10.60 per square metre. Lifetime benefits range from about $130 per square metre up to $230.

As a comparison, the current costs of green roofs are said to be in the range of $150 to $400 per square metres so long as extra engineering works are not needed. Intensive green roofs can be more expensive. Operating costs are also not included.

Adding other benefits that were not included and updating these estimates with local data would result in combined public and private benefits being positive over the full life cycle of most green roofs.

Less data is available for green wall and façades but a similar set of outcomes could be expected. Water-related benefits would be lower, but cooling benefits measures over horizontal areas are greater, and there is more potential for cooling at street level.

Cities around the world are mandating green roofs, walls and façades for building upgrades and new buildings. A number of incentive schemes are in place to ensure an ongoing flow of public benefits. Melbourne is not as far down this path as other cities, but with urban liveability and resilience to a changing climate as a priority there is a need to catalogue the benefits in preparation for an accelerated transition.

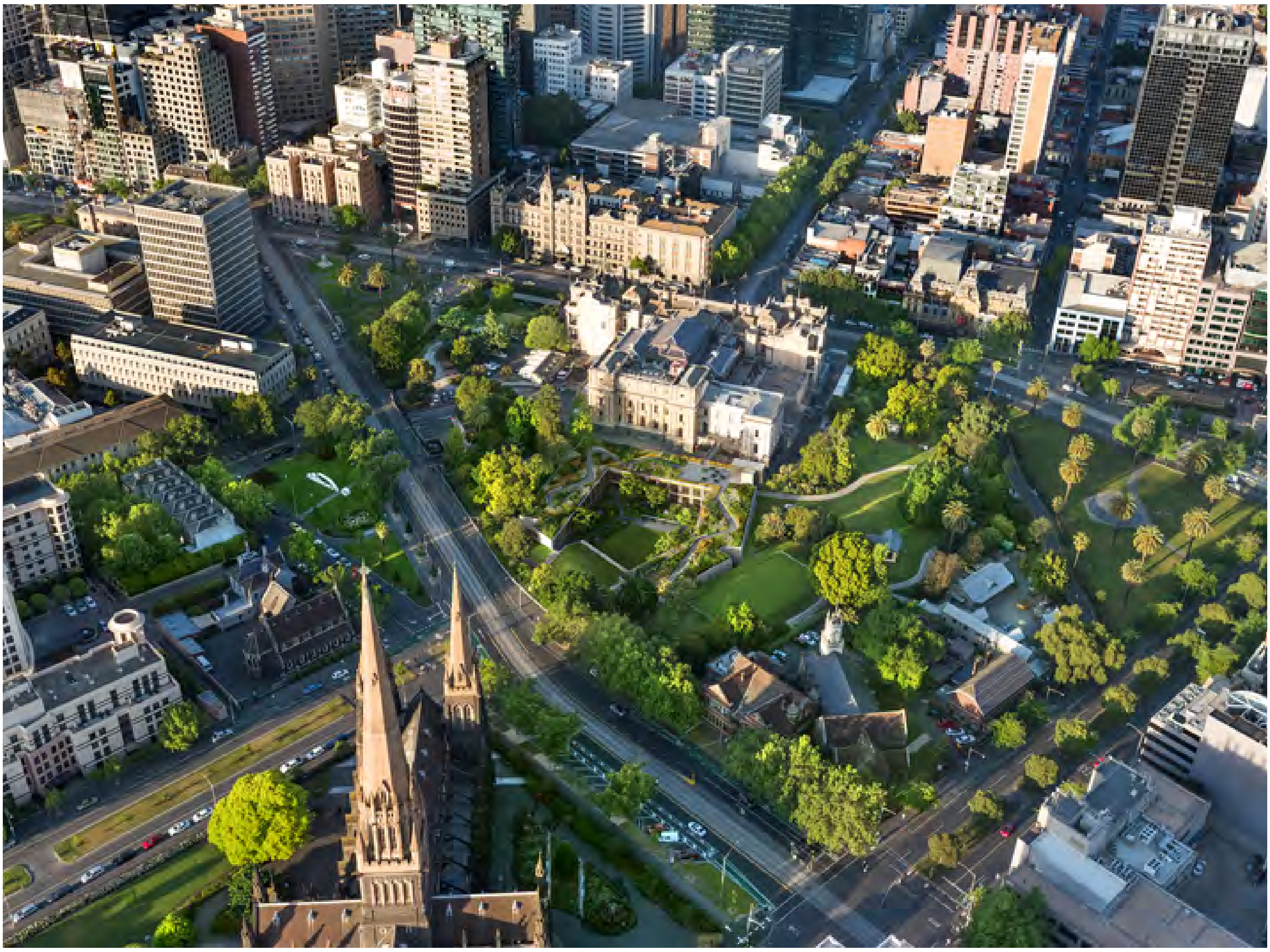

Figure 27. Artistic rendition of the new Parliament House extension, Melbourne.

# APPENDIX I - ACKNOWLEDGEMENTS

This guide is based on the report *Quantifying the Benefits of Green Infrastructure: Literature Review and Gap Analysis. A report to the City of Melbourne,* written by Roger Jones, Rachael Bathgate, John Symons and Nick Williams from the Institute of Sustainable Industries and Liveable Cities, Victoria University, Melbourne and Green Infrastructure Research Group, School of Ecosystem and Forest Sciences, University of Melbourne.

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# APPENDIX II – PHOTO REFERENCES

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Figure 1. Previous page shows roof garden at Kangan Institute, Melbourne.

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Figure 3. Triptych Apartments, Southbank – Gail Hall/ Julie Francis.

Figure 4. Roden St, West Melbourne – City of Melbourne.

Figure 7. Freshwater Place, Southbank - Sue Murphy.

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Figure 9. The Burnley Biodiversity Green Roof at the University of Melbourne – University of Melbourne GIRG / City of Melbourne.

Figure 10. Victorian Comprehensive Cancer Centre – Peter Bennetts, courtesy of Plenary Group.

Figure 11. Elizabeth Street Catchment Integrated Water Cycle Management Plan, City of Melbourne 2015.

Figure 12. Artistic rendition of Parliament House extension – Parliament of Victoria, Peter Elliott Architecture and Urban Design.

Figure 14. Triptych Apartments, Southbank – Gail Hall/ Julie Francis.

Figure 15. The Burnley Biodiversity Green Roof at the University of Melbourne – University of Melbourne GIRG / City of Melbourne.

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Figure 17. The Burnley Biodiversity Green Roof at the University of Melbourne – University of Melbourne GIRG / City of Melbourne.

Figure 18. Victorian Comprehensive Cancer Centre – Peter Bennetts, courtesy of Plenary Group.

Figure 19. Greenwich Village Elementary School, New York City – Aloha Jon.

Figure 20. Medibank building - Kelly Hertzog, City of Melbourne.

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Figure 25. Green roof and gardens, Vancouver, Canada.

Figure 26. The Venny, JJ Holland Park, Kensington - City of Melbourne.

Figure 27. Artists rendition of Parliament House extension – Parliament of Victoria, Peter Elliott Architecture and Urban Design.



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# APPENDIX III – REFERENCES


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