An introduction to green roofs, walls and facades
Cities are increasingly trying to get back to nature and blur the distinction between the urban environment and the broader landscape. Around the world, and in Melbourne itself, more and more walls and roofs of buildings are being covered with living plants. From the creepers that quietly cover greater amounts of a wall as they expand from a garden, to the fanfare that accompanies the development of major ‘artworks’ of living walls in public spaces, to the home-made green roofs on backyard sheds, and the increasing number of inner city bars with rooftop gardens …. we are seeing a transformation in the city and a new appreciation of living plants as part of the built environment.
A future with buildings covered in vegetation relies on the development of quality roofs, walls and facades, and commitment to ongoing maintenance.

In 2011 there were an estimated 87 green roofs in Victoria. There are untold numbers of green facades and in 2013 an estimated 10-20 green wall installations in central Melbourne. Much greater numbers of green roofs, walls and facades are possible in Melbourne, and in other parts of Victoria. Urban environments with these features would be cooler and more pleasing to live among and they would provide new habitat for insects and birds. In addition, with good planning, vegetation grown on buildings could provide urban environments with greater resilience in heavy rainfall events.

Building owners could also have significantly reduced power costs from heating and cooling, as rooftop plants and the ‘soil’ they grow in act as a layer of insulation.

A future with buildings covered in vegetation relies on the development of quality roofs, walls and facades, and commitment to ongoing maintenance. This needs to be underpinned by a knowledge of how best to design, construct and maintain green roofs, walls and facades, which is understood by architects, engineers, builders, developers, building owners, government planners and urban designers, landscape architects and those involved in installing the products and equipment to create these urban innovations. This guideline has been put together with the best knowledge and advice that industry and researchers have to date, in order to enable the building and design industry, and any building owners, to create and maintain green roofs, walls and facades that can help change the face of our urban environments into the future.

These guidelines have come about from the commitment of a great number of people who are already involved in designing, constructing, maintaining and researching green roofs, walls and facades. The development of guidelines has been supported by four inner Melbourne local governments, the Cities of Melbourne, Port Phillip, Yarra and Stonnington, the University of Melbourne and the State Government – through the Victorian Adaptation and Sustainability Partnership. Through the commitment and passion of these people and organisations we hope to propel a revolution in urban landscapes in Victoria, and we invite you to be a part of it.
Definitions

Green Roof
A vegetated landscape constructed on a roof that consists of various layers, which can be installed either in modules or ‘loose laid’ over the top of the roof.

Green Wall
A modular, container system, or a fabric-based growing system, erected directly on a building wall and supporting largely herbaceous plants.

Green Facade
Plants grown directly over a building wall, either climbing up or hanging down, or climbing plants using cabling or a trellis support structure adjacent to a wall. Plants can be grown in ground or in containers.
The case for green roof, walls & facades

Around the world more and more leaders in city design, development and planning are calling for ‘green infrastructure’, ‘biophilic urbanism’ and ‘greener cities.’ These terms encompass an interest in green roofs, walls and facades, as well as parks, gardens, wildlife corridors, community gardens, wetlands, running water in cities, and a range of other initiatives that incorporate a greater degree of the natural environment into the urban landscape.

This interest has been bolstered with the confluence of several streams of thought about why integration of the built and natural environment is beneficial in cities. On the one hand there has been significant research in the health field about the benefits that come with being surrounded by green space – for both mental and physical health. Also, research has shown that the interaction of people with the natural environment increases pride of place and is a catalyst for community building. There is a growing popular interest in urban food production and sustainable design, which generates demand for more green spaces, more eco-friendly buildings and regulatory flexibility that allows individuals to explore urban agriculture in and around their properties and public spaces.

There has been much research on the value of biodiversity conservation and urban ecology, and the need to consider the wider environment, not just human needs, in cities. Finally, adding weight to the interest in greener cities, research on climate change resilience indicates that people and the urban systems they depend on (water pipes, roads, buildings) will be better off if they exist within a resilient and healthy natural environment. This research has led to increasing interest in using vegetation to protect shorelines from storm surges and to filter and slow down run off from intense storms, to cooling a city with vegetation to mitigate against intense heat waves and simply encouraging native wildlife back into places they once inhabited. Green roofs, walls and facades are seen as particularly interesting by many for the multiple benefits they can provide. These benefits are explored in the following pages.
Benefits of green roofs, walls & facades

Cleaning the air
Plants on green roofs, walls and facades can be effective at removing pollutants from the air - depending on the type of plant, leaf surface and leaf tissue. Green walls planted with vines have a very dense leaf area per square metre and have been shown to be good in removing particulate matter. Green roofs and walls also help improve air quality by controlling heat gain and the associated generation of smog.

Cooling a city - Urban heat island effect
Hard surfaces in urban environments such as buildings, conventional roofs, roads and parking lots are related to a rise in ambient temperature, known as the Urban Heat Island Effect. This condition can lead to negative effects on days of extreme heat in urban environments (heat related illness, ground level smog formation). Green roofs and walls, implemented as a city-wide strategy, can mitigate the heat island effect. By introducing vegetation onto roofs and walls, temperatures can be reduced by means of evapotranspiration (evaporation of water from the soil and plants, and plants transpiring by taking water in through roots and releasing it through leaves) and simply through covering the roof with a less absorbing surface. Energy from incoming solar radiation that would otherwise heat the roof or wall surface and increase ambient air temperatures is instead used in the evapotranspiration process, resulting in latent heat loss that lowers surrounding air temperatures.

A study in Toronto, Canada, modelled the effect of green roofs on the urban heat island and concluded they would reduce local ambient temperature by 0.5°C to 2°C. It was calculated that this would result in $12m in savings from reduced energy demand for cooling.

Creation and preservation of habitat & ecological biodiversity
Green roofs can contribute to conservation and enhancement of biodiversity by creating new links between existing habitat areas and providing additional habitat for rare or otherwise important species. Green roofs can provide a link for migration of insects and birds and provide biodiversity benefits for a range of plant, invertebrate and bird species, if consideration is given to this at the design stage. The potential for biodiversity depends on plant species and height, food sources and building height.
Storm water management

Green roofs absorb and retain water and are therefore one strategy for controlling stormwater runoff in urban environments. Green roofs influence run-off by intercepting and retaining water from the early part of the storm, and limiting the maximum release rate of run-off in larger storms. Water is stored in the substrate, used by the plants, or retained in plant foliage and on the substrate and evaporates. Additional water storage capacity is available in green roof systems which have a water retention layer. In addition to helping slow and reduce storm water run-off, green roofs can also filter particulates and pollutants.

A number of elements influence the extent to which a green roof can control the volume of water running off. The vertical depth of the growing substrate and drainage layer, consistency and porosity of the growing substrate, structure of the drainage layer, and slope of the site. The type of plant species and type of drainage system are important factors to consider when designing a green roof system for water treatment. The run off diversion for green roofs is also influenced by the weather conditions of the region. The length, intensity and frequency of rain events will influence a green roof’s ability to retain water.

Aesthetics, open space & urban agriculture

Liveability of cities, especially those undergoing rapid population growth and building development, is dependent on availability of open space. Green roofs help increase amenity and open space, can encourage community gardens and food production, and can extend commercial and recreational space.

It has been found that including greenery in the cityscape reduces stress and patient recovery time, improves worker productivity, decreases noise, increases property values and has been linked to a reduction in crime.

Urban agriculture is commonly discussed as a way to ensure food security, enhance community participation in the food system and improve health. Food producing gardens located on rooftops can be places for education and local distribution, as well as a showcase for commercial endeavours.

The importance of green roofs, walls and facades in providing green space in dense urban areas should not be underestimated. Especially in inner Melbourne, it can be difficult to create new areas of parks and gardens, where most space has been taken up with built infrastructure.
Benefits for building owners

Green roofs, walls and facades are increasingly used by building owners to add a point of difference to their building. The green façade or wall can add an element of prestige and beauty to a building. The green roof can be a versatile space used for recreation, urban agriculture or commercial space for a bar or café.

The construction of a green roof, wall or façade can happen relatively independent from the rest of a building project and therefore poses very little risk of delaying the construction of a new building. That said, it is still very important to include the installation specialists in early discussions of the construction project timelines, to get the most efficient timetable of construction.

Internationally and in Melbourne, it has been suggested that if a building is more aesthetically and environmentally desirable, there are economic benefits in terms of lease outs, property values and employee recruiting. Due to the increased consumer interest in green buildings developers are often looking to Green Star and National Australian Built Environment Rating Schemes, green roofs, walls and facades are increasingly being considered to help achieve points toward these ratings.

Building owners also find a benefit in green roofs through additional protection of the roof’s waterproofing membrane – by covering it with a layer of organic and inorganic insulation. This reduces the stress placed on the membrane by preventing severe fluctuations in temperature. The protection afforded to roofs is especially important in Australia where exposure to ultraviolet radiation can be extreme.

One of the biggest benefits of green roofs, walls and facades for building owners is in reduced heating and cooling costs. The insulation provided by green roofs reduces heat transfer through the roof and ambient temperature on the roof surface, resulting in better performing Heating Ventilation and Air Conditioning (HVAC) systems. Green walls and facades provide insulation by direct shading of the building surface, and from passive cooling due to transpiration. When plants are grown on a support system that leaves a gap between the wall and the vegetation, hot air moves by convection up through the space between the wall and the plants. All green roof, wall and facade systems provide local cooling through evaporation of water and transpiration by plants. Evaporation from felt-based green wall systems will be significant because they are constantly irrigated.

Whilst there is great potential for cooling of buildings via vegetation, the research results vary significantly in how much difference in temperature, and effect on energy savings can be detected between buildings with green roofs and conventional roofs. The variety in results is because the amount of energy saved depends on a range of factors including:

- the percentage of rooftop covered by a green roof
- the thickness of additional insulation used in the installation.
- the height of the building (the floor directly under the green roof receives most benefit)
- the type of vegetation used and depth of the soil substrate
- roof to wall ratio
- climatic conditions and microclimate of the building
- HVAC efficiency

As such, it is important to very carefully design the roof, wall or façade to maximise the cooling potential of the installation.
Green roofs are often described as extensive or intensive. Extensive green roofs are generally designed to be lightweight and to maximise the performance and environmental benefits that a green roof can bring to a building. Extensive green roofs feature a layer of growing substrate that is 200mm deep or less, and are generally planted with succulents, grasses or native plant species. This means they have very low water requirements. Extensive green roofs are not usually accessible to the public, unless decks or walkways are provided. Intensive green roofs are generally designed as amenity space that can be used by building tenants or by the general public. Intensive green roofs are generally heavier, include a deeper layer of growing substrate, support a wider variety of plants, and have greater needs for irrigation and maintenance. Irrigation of green roofs can be either manual, with a hose, if the space is easily accessible and small enough for one person to manage, or an automatic watering system can be installed. Good drainage is imperative to avoid waterlogging or plants or structural damage due to excess weight on the roof. Often a roof can only support intensive plantings in particular areas, where it has most strength, and otherwise has extensive green roof plantings, this combination is called a semi-intensive roof.
Facade greening may cover a building by the growth of climbing plants up and across the face of a building. Generally only one or a few species are planted, providing a fairly uniform look to the building. Plants may be planted in the ground, or in containers placed at different heights up the face of a building. Therefore, water must be supplied to either the garden bed in the ground or to the containers, the latter needing more irrigation than the former. Although plants may trail down from containers, extensive cover of a wall is typically achieved by upward growth of plants. There are facades that use no support systems, where the plant clings onto the building, and facades that use cabling, trellis or other supports, where plants twine around the supports. The decision for which type of façade comes from whether the building owner has a preference to separate the vegetation and building wall (more costly because a support structure must be built) and depends on which species of plant is used – one that can adhere to a building or one that has tendrils and requires some wire or cabling to attach to.
Green walls can be built onto internal or external walls, however adequate light is a big constraint for internal walls. There are two main approaches used in green wall design and construction, felt fabric mounted plants and modular, containerised systems. The former involve two layers of felt, or similar material, mounted and bound onto a waterproof support board. Pockets are made in the front layer of felt to hold plants using a small volume of growing substrate. An irrigation system is installed to sustain plant growth. Modular green wall systems involve a support framework of steel or high-strength plastic that holds and supports the weight of growing containers, irrigation system, growing substrate and plants. Green walls need a high level of irrigation – water must be supplied to the roots because the roots do not have access to significant amounts of soil. Water can be recycled through the system, but this needs careful monitoring to ensure nutrient levels do not build up to dangerous levels. The irrigation system is often used for periodic fertigation although fertiliser can also be included as part of the growing medium.
Why might you choose to install a roof, wall or facade?

Green Facades
Facades have fewer components than the other options, which can make them simpler and cheaper to install. Green facades are generally installed because they provide an attractive look to a building wall or are being used to shield from view items which might be behind a fence. Facades are sometimes installed for reasons of growing food producing plants, for providing habitat or for providing a cooler microclimate next to a building through shading and evapotranspiration.

Green Walls
Walls can include many different plant species and therefore are installed for a more varied look to what can be achieved by a façade alone. Like facades, they can be an ideal place for providing a view of greenery when roofs or ground do not provide space. Walls are often installed as an architectural design feature and to add prestige to the building.

Green Roofs
Roofs are often constructed to create a space for people to visit, as an architectural feature and point of difference for the building, or for building insulation, noise reduction or roof protection. Well-designed green roofs can be used to reduce stormwater runoff, provide bird and insect habitat, or cool the urban environment.

How to further explore green roofs, walls and facades

If you think that green roofs, walls or facades are something that you would like to further investigate, read on to Section 2 of these Guidelines to learn more about the component parts, design considerations and advice on construction and maintenance. It is important to get a structural engineer’s advice on the load bearing capacity of your roof or wall, and to speak to green roof, wall or façade installation companies to learn more about your options. Visiting existing sites is a great way to learn more about what works and how the finished product might look.
Through the commitment and passion of the people and organisations who helped put together this guide we hope to propel a revolution in urban landscapes in Victoria, and we invite you to be a part of it.
**FREQUENTLY ASKED QUESTIONS**

**Do green roofs work on new and old buildings?**
Yes. Green roofs can be fitted to a range of roof types. A new building can be constructed to facilitate the required weight loading of a designed green roof, while an existing building could be retrofitted to take a heavier loading. Some existing buildings already will have the capacity for a green roof, but in any case a structural engineer should be consulted before considering a green roof to ensure an appropriate roof can be built.

**Can both the suburbs and the city centre realistically have green roofs?**
Yes. While not all existing buildings are appropriate for green roofs, it has been estimated that at least 20% of central Melbourne’s buildings could support a green roof. All new buildings have the potential to include green roofs, they just need to be designed with appropriate weight loading capacity. Buildings that are the least likely to support a green roof are those that have:
- steep roof pitch;
- low weight loading capacity;
- significant height and limited access (i.e. are difficult and expensive to construct; and
- considerable roof infrastructure (e.g. HVAC equipment, limited solar access, etc.)

If a green roof is not an option, a green wall or façade might be possible.

**Can I have a green roof on a slope?**
Yes, but not those roofs that are very steep. Specialised design solutions exist for sloping green roofs, including drainage boards and profile build-ups that can assist in retaining substrates and plants successfully.

**Can a tile roof be greened?**
Yes, but it requires design expertise and specialised systems that are as yet not widely available in Australia.

**Is irrigation necessary for a green roof, wall or façade?**
In many situations you can establish a green roof successfully with no irrigation but the choice of plants you can use will be very limited and some potential benefits (such as summer cooling) will be reduced. All green walls and most green facades, other than some garden bed grown settings, will require irrigation.

**How much water do you need?**
There is no one answer, as calculating the water needed to sustain a green roof, wall or façade is dependent on the vegetation, the substrate, the influence of climate and exposure and the design of the system. Alternative sources of water for use, including harvested and recycled water should always be explored to minimise use of potable water. Many green walls rely heavily on irrigation and require careful calculation to ensure supply can meet demand.

**Will the roof leak and cause problems?**
A green roof system does not make the roof more likely to leak, but it will make it more difficult to repair if a leak occurs. Properly constructed green roofs, walls and facades will not leak or cause other problems. Correct installation of waterproofing will ensure you have no problem with your roof or wall.

**Will plants ‘overtake’ the roof?**
Vegetation maintenance on a green roof is important and should be factored in to the design and management of the project. Selection of less vigorous plants, those with low biomass or those that do not seed freely can reduce the required maintenance inputs. Green facades need careful species selection so that less vigorous plants are installed that are unlikely to damage the building wall. If concerned about the building wall, a green façade on a support structure might be more appropriate, or a green wall, which is a contained system mounted to the wall, but separate.

**How much do green roofs, walls and facades cost?**
Costs will vary significantly between sites and projects, the case studies provided in Section 2 of the Guidelines give an indication of costs for comparable projects.

The key factors that influence cost are:
- The size of the roof, wall or façade;
- The design and type of materials used in the roof (e.g. structural reinforcement and inputs, substrate (soil) volume, plants, system components, hard surfaces and furniture, etc.)
- Access to and within the roof space

**Can I have solar panels on a green roof?**
Yes. In fact there is some evidence that solar panels can work more efficiently on a green roof rather on a conventional roof, due to the lowered surface temperatures afforded by the vegetation.

**How do I know if my building has the capacity for a green roof?**
For a new building, your architect should ensure that a green roof can be properly built (subject to Council approval). For an older building where you are seeking to retrofit a green roof, a discussion with an architect and/or structural engineer will be required in the first instance.

**What is the typical lifespan for a green roof, wall or façade?**
The lifespan of a roof, wall or façade is directly related to appropriate plant selection for the site and the quality of the design, construction and maintenance, particularly the longevity of system components. Some green roofs in Europe have lasted for more than 50 years and are still going, others have struggled to last 10 years. There are examples direct façade greening in Melbourne that have lasted decades, however some green wall and façade technologies are more recent, so lifespan issues have yet to be fully evaluated.