INNER WEST

Green Roofs, Walls and Facades

2020

Technical Guidelines

Inner West Council acknowledges the Gadigal and Wangal peoples of the Eora nation, who are the traditional custodians of the lands in which the Inner West Local Government Area is situated.

LGA Wards

Balmain Ward – Baludarri (Leather Jacket)
Leichhardt Ward – Gulgadya (Grass Tree)
Ashfield Ward – Djarrawunang (Magpie)
Stanmore Ward – Damun (Port Jackson Fig)
Marrickville Ward – Midjuburi (Lillypilly)

This publication has been prepared by Inner West Council (IWC).

Acknowledgments
Inner West Council would like to acknowledge the authors of two documents on which this Guideline is based - the Urban Green Cover Technical Guidelines for NSW (OEH, 2015) and the Growing Green Guide (Department of Environment and Primary Industries, 2014)

Revision Table

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Cover image: Green wall, Rozelle (source: Green Roofs Australasia, 2018)
Inside cover image: Fish Traps scuplture by Edwards Clarke, King George Park Rozelle (source: Barbara Becker, 2019)

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1. About the Guidelines

Purpose

The Green Roofs, Walls and Facades Technical Guidelines for the Inner West provides technical advice to support the installation of green roofs, walls and facades in the Inner West. It gives an overview of how to plan, design, build and maintain green roofs, walls and facades.

The Inner West is undergoing significant population growth and change. This presents opportunities to enhance the area with green infrastructure to create a more liveable, resilient and sustainable community and environment.

The installation of green roofs, walls and facades throughout the public and private domain greatly enhances liveability whilst providing environmental improvements.

This technical guide has information on green roofs, walls and facades for:

- building owners and tenants
- property and facility managers
- builders and developers
- project managers
- designers including landscape architects, architects and engineers
- local government officers

This guide contains practical information and tools including checklists and design specification guidance to help those interested to understand, plan, design and construct green roofs, walls and facades.

Green Infrastructure

Inner West Council recognises the importance of green infrastructure to provide ecosystem services and other benefits (Our Inner West Community Strategic Plan, 2016).

Green roofs, walls and facades are types of green infrastructure. Environmental, social and economic benefits of green roofs, walls and facades include:

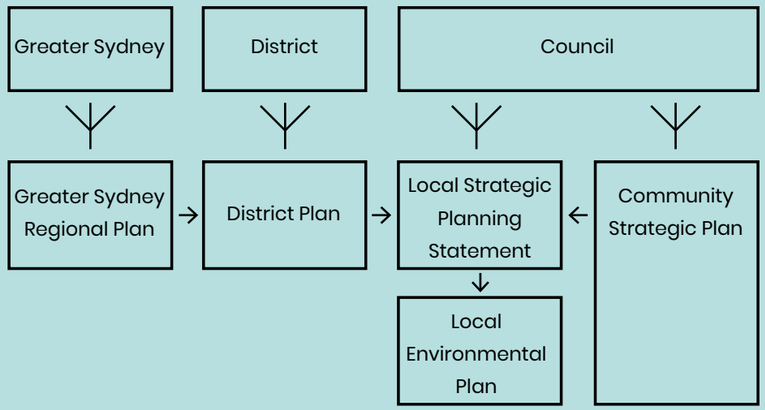
- countering climate change impacts, such as the Urban Heat Island effect
- improving human health and wellbeing
- enhancing biodiversity
- improving the quality of water before it enters waterways
- managing the quantity of stormwater and rain water
- reducing flooding
- recycling greywater
- reducing heating and air-conditioning needs
- filtering pollutants from air
- increasing the life span of roof structure

> Green infrastructure is “the network of green spaces, natural systems and semi-natural systems including parks, rivers, bushland and private gardens that are strategically planned, designed and managed to support a good quality of life in an urban environment.”
> (Government Architect NSW, 2017)

Strategic Context

To drive the delivery of green infrastructure in NSW, the Greater Sydney Commission, NSW Office of the Government Architect and Department of Planning, Industry and Environment (including the former the Office of Environment and Heritage) have a range of plans, policies and guidelines. They include the:

- Eastern City District Plan (Greater Sydney Commission, 2018)
- Draft Greener Places policy (NSW Office of the Government Architect, 2017)
- Urban Green Cover in NSW Technical Guidelines (OEH, 2015)



Relationships between regional, district and local plans (source: Adapted from Greater Sydney Commission, 2018)

Strategy 1.1 of Council’s Community Strategic Plan (2016) is to “Provide green infrastructure that supports increased ecosystem services.”

Inner West Council’s Local Environment Plan (LEP) and Development Control Plan (DCP) provide additional guidance for implementing green roofs, walls and facades in the Inner West.

2. What are green roofs, walls and facades?

a. Green Roofs

Green roofs are roof surfaces that are partially or fully covered with vegetation. They have a series of layers including a vegetated layer, a growing medium, and a waterproof membrane (Leichhardt Council, 2013).

Green roofs are made up of the following components: roof structure, thermal insulation, waterproofing membrane, leak detection layer, root barrier, drainage layer, geotextile fabric/filter layer, growing medium or substrate, plants and irrigation system.

There are 2 main types of green roofs:

1. Extensive – shallow substrate

An extensive green roof has a growing medium (i.e. soil mix) of approximately 150mm deep. As a result, it is lighter in weight and in many cases can be retrofitted to existing buildings. Plant species suitable for extensive green roofs are low growing ground covers or grasses requiring minimal maintenance. Extensive green roofs are typically more cost effective and are usually non-accessible or have limited access (OEH, 2015).

2. Intensive – deep substrate

An intensive green roof has a growing medium of typically more than 150mm deep. It is heavier than an extensive green roof and requires a stronger roof structure. It is capable of sustaining larger plant species, including shrubs and trees (OEH, 2015). Intensive green roofs are typically more accessible and open for people to use. They are also known as rooftop gardens.

Extensive green roof, Rozelle
(source: 202020 Vision, 2018)

b. Green Walls and Facades

Green walls and facades are vertical structures covered with vegetation. They either free-standing or part of a building or other vertical structure that is partially or completely covered with vegetation. They are also referred to as living walls, green facades, bio-walls or vertical gardens. They can refer to specific designs, construction techniques and scales of implementation, located on a vertical structure (Department of Environment and Primary Industries, 2014).

Green Walls

Green walls may incorporate soil and/or inorganic material as its growing medium (Leichhardt Council, 2013). Green wall systems can be constructed from pre-vegetated panels that hold growing media to support the plant material or planted blankets with planting pockets filled with plants and growing media. These systems are fixed to a structural framework or to a wall. They are typically capable of sustaining a diverse mix of plant species including climbers, groundcovers, grasses and small shrubs.

Green Facades

A green facade is a system that mimics self-clinging plants but uses an engineered, trellis system to support climbing plants on the vertical facade of a building. Plants can either be grown in-ground or in planters at intermediate levels (Government Architect NSW, 2017). Self-clinging plants have been used to create green walls for centuries but often their sucker root system damaged the structural integrity of the wall. Green facades today include a structure for plants to grow on to prevent this.

Green wall, Macquarie Park bus shelter
(source: Junglefy, 2018a)

Hybrid Green Wall
Hybrid green walls use both green facade and green wall technology to create a hybrid version of vertical greening.

Interior Green Walls
Interior green walls, sometimes known as living walls, can be designed and constructed using either the panel, felt or trellis system. Lighting requirements are a major design consideration for interior green walls, especially where natural light is low and artificial light may be required (OEH, 2015).

Breathing Walls
Breathing walls are green walls that are specifically designed to filter and remove polluted air and provide clean air for the surrounding area (Junglefy, 2019). They can be located inside or outside.

Interior green wall, Woolahra Library, Double Bay.

3. What are the benefits of green roofs, walls and facades?

Green roofs, walls and façades provide numerous environmental, social and economic benefits. They also help the Inner West comply with state and IWC plans such as the Eastern City District Plan and the Inner West Community Strategic Plan.

a. Environmental benefits

Green roofs, walls and facades provide the following range of environmental benefits.

Reduced carbon footprint

Green roofs, walls and facades provide additional urban greening which has a range of environmental benefits, including climate change mitigation and adaptation. Green roofs, walls and facades can help to reduce a city's carbon footprint through the capacity of the vegetation to absorb carbon (Davies et al., 2017).

Air purification

They can filter air particles, provide oxygen, humidify the air, and absorb carbon dioxide and pollutants. Indoor green walls can form part of a building's air circulation system, such as the breathing wall system which uses fans to direct air through the green wall. The plants then remove pollutants and increase oxygen in the air before circulating that clean air throughout the building (Torphy et al., 2015). This technology can also be used outdoors.

Reduced temperatures and noise

Green roofs, walls and facades moderate urban temperatures. Outdoor green roofs and walls provide thermal mass to a building to increase insulation. Evaporation from leaf surfaces provides a cooling effect on air temperature. Research has shown green walls can reduce adjacent pavement temperatures by 5°C through reduced building surface temperature and surrounding ambient air temperature (Hopkins et al., 2012). A study of two green roofs in Melbourne found that the air temperature at the vegetation was 5.3°C - 6.2°C lower than the ambient temperature, and that when surface temperatures of an adjacent concrete roof surface rose to 55°C, the soil temperature under the plants was 20°C - 24°C (Rajagopalan & Fuller, 2010). Green roofs and walls also provide sound insulation to reduce levels of noise.

Increased habitat and biodiversity

Green roofs, walls and facades can contribute to increased biodiversity particularly when planted with native plant species. They provide additional habitat for flora and fauna in urban areas (Berthon et al., 2015). Intensive green roofs and green walls typically have the greatest potential to improve urban biodiversity because they are designed to grow a more diverse range of plants.

Reduced rainwater run-off and improved water quality

Green roofs and walls help manage stormwater by slowing water during peak rainfall events, decreasing effective impervious area and minimising the risk of flooding downstream. Water is slowed when it lands on the permeable surface and is absorbed and filtered by plants and growing media. This water can be harvested and re-used for non-potable uses such as landscape irrigation and toilet flushing (Beecham & Razzaghmanesh, 2015). Green walls can also be designed to treat greywater and stormwater (Fowdar et al., 2018).

Potential environmental benefits include:

- **reduced carbon footprint**
- **air purification**
- **reduced temperatures and noise**
- **increased habitat and biodiversity**
- **reduced rainwater run-off, rainwater harvesting**

b. Social benefits

Green roofs, walls and facades improve health and wellbeing.

Psychological benefits

Human interaction with green space and plants has long been identified as a key to positive mental health and wellbeing. Green roofs and walls provide people living in urban areas with psychological benefits. Oberndorfer et al. (2007) reported a range of benefits from viewing green roofs, including relaxation and restoration and Loder (2011) reported reduced stress, a calming effect and feelings of happiness.

Improved concentration and productivity

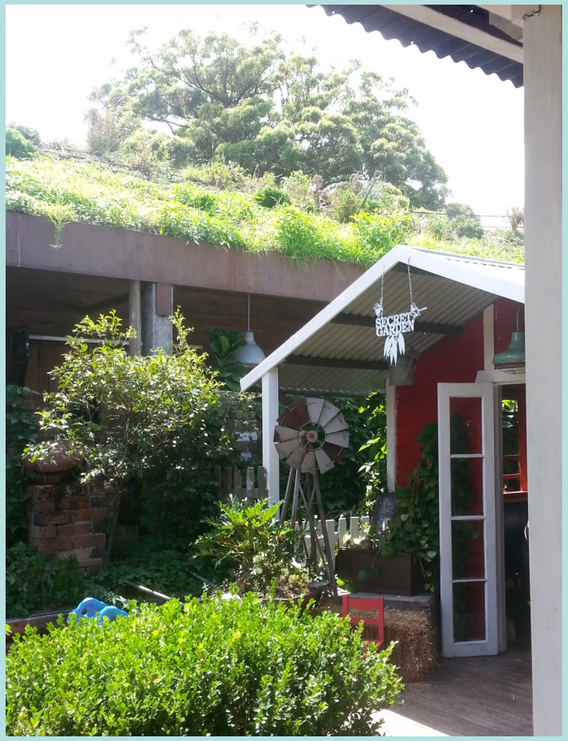
Research shows that exposure to green walls improves concentration and productivity. For example, a study of 150 University of Melbourne students showed that a 40-second view of a green roof improved attention, efficiency and accuracy when completing a task (Lee et al., 2015).

Additional space for recreation and open space

Green roofs which are designed to be accessible create additional space for recreation and open space. They provide space for family and community life, and support social and cultural opportunities.

Reduced heat-related illness and death

Keeping buildings cooler through increased shading and insulation is likely to contribute to a reduction of heat-related illness and death, and the demands on health services associated with extreme hot weather (Victorian Department of Health, 2012).



Green roof, The Grounds of Alexandria, Alexandria.

Potential social benefits include:

- **psychological benefits**
- **improved concentration and productivity**
- **space for social, recreational, cultural activities**
- **reduced heat-related illness and death**
- **improved visual amenity**
- **improved screening and privacy**

Improved visual amenity
They improve the visual amenity and liveability of the city by helping create a sense of place. Their distinctive forms, textures and colours create seasonal interest that imparts a unique character to a particular place.

Improved screening and privacy
Green roofs and walls can help screen undesirable views and provide privacy, which is especially important in dense urban areas.

c. Economic benefits

The benefits of green roofs, walls and facades also extend to long-term financial savings.

Reduced energy requirements
Green roofs, walls and facades reduce energy requirements of buildings by:
- providing thermal insulation which reduces the energy requirements of a building
- providing shade
- reducing heating and air-conditioning requirements, expenditure and greenhouse gas emissions.

Modelling of energy savings for buildings with green roofs in Sydney shows annual heating and cooling savings of 27% - 31%, mainly due to lower cooling costs (Adhikari and Savvas, 2016).

Increased life span of roof structure
Green roofs can increase the life span of the roof structure by extending the life of their supporting structure and substrates. By preventing direct solar impact on waterproofing membranes, a green roof protects against damage from ultraviolet radiation and from constant heating and cooling of the membrane. A vegetated roof can extend the life of a conventional roof by at least 20 years and reduce regular maintenance costs (McGee, 2013).

Additional space for food production
Green roofs and walls also provide space for urban food production. This can be particularly effective in dense urban environments where they can compensate for the loss of productive landscape at ground level.

Reduced costs of emergency flood works
Green roofs can reduce the costs of dealing with the increase in peak rainfall events associated with climate change by retaining stormwater and slowing rainfall runoff. Student research at the University of Queensland has shown runoff reductions of up to 42% achieved with 100mm of soil planted with moderate growth turf. As the soil depth and vegetation water use is increased, so does retention capacity (McGee, 2013).

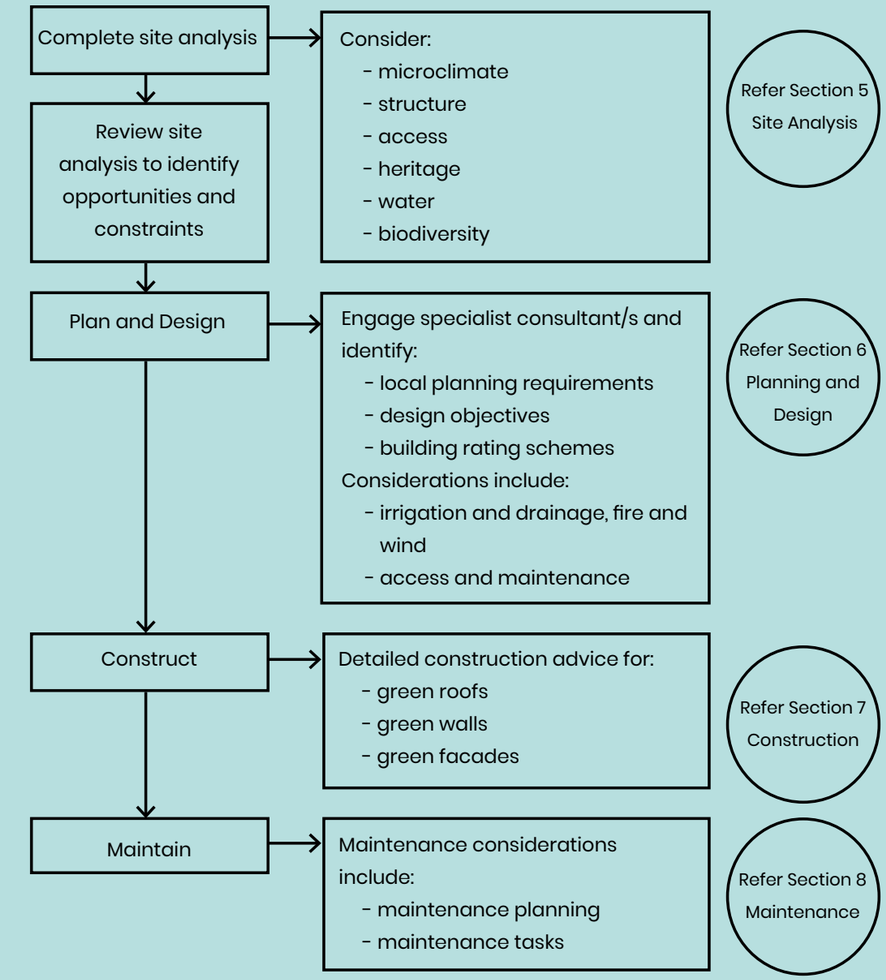
Increased efficiency of solar panels
Green roofs improve the efficiency of solar panels. By lowering ambient roof temperatures, green roofs enable solar panels mounted over them to operate more efficiently, with energy outputs up to 15% more than from panels on asphalt or gravel covered roofs (McGee, 2013).

Potential economic benefits include:
- **reduced energy requirements**
- **increased life span of roof structure**
- **additional space for food production**
- **reduced costs of emergency flood works**
- **increased efficiency of solar panels**
- **reduced health care costs**

4. Design process and considerations

Five key steps to building a green roof, wall or facade are detailed in the following chapters, outlined in the flow chart below. The rest of this technical guideline provides more details about each of these steps.

Depending on the size of the project, a specialist consultant may be engaged once it has been decided to build a green roof, wall or facade. This consultant would be the lead consultant and they would:
- co-ordinate sub consultants
- typically be a landscape architect or a project manager, depending on the size of the project.



5. Site Analysis

This section provides an overview of some typical factors to consider before designing a green roof, wall or facade on a new or existing building. When considering a green roof, wall or facade, it is important to understand the existing characteristics of the site. Visit the site multiple times to get to know the existing conditions and become familiar with the site if this is not already the case. A thorough site analysis will help inform the design and ensure the long-term success of the project.

a. Microclimate

Each site has a different microclimate. The localised climate of the specific site needs to be carefully considered as it influences how the proposed green roof, wall or facade is designed. Sun, shade and wind conditions will influence plant selection during the design phase, as they change the growing conditions.

Sun and shade

Consider the amount of sun and shade the proposed location receives by identifying:

- the orientation of the roof or wall and any overshadowing
- if there is other vegetation nearby and if there is overshadowing from that vegetation or other buildings nearby
- the maximum and minimum temperatures of the location
- if there is any reflection from adjacent buildings or other structures

Wind exposure

Wind exposure varies depending on the location, height and orientation of the building. Nearby structures can cause wind tunelling effects. High wind has a dehydrating effect on vegetation and should influence species selection and irrigation requirements. Green roofs, walls and facades need to be able to withstand these wind conditions.

Consider the likely wind load that a green wall, roof or facade will be subject to by identifying:

- the height above ground
- if there are nearby buildings
- typical wind direction and speed

Wind information can be found on the Bureau of Meteorology website including wind rose diagrams showing the frequency of occurrence of wind speed and wind direction.

Civil and/or structural engineers will provide more detailed advice and recommendations in the design phase, depending on the site and design. Where necessary, plants and any associated structures must be anchored to the building so that they cannot detatch and cause damage (National Parks Board, 2018).

b. Structure

Determine the properties of the new or existing structure on which the green roof, wall or facade is to be built.

Size, slope and plant equipment

Consider what might be the appropriate size of a new green roof, wall or facade by identifying:

- the size of the roof or wall
- the slope of the roof
- if there is any existing plant equipment (such as mechanical units like air-conditioning units) on the rooftop or fixed to the wall, and whether it can be relocated or reduced in size.
- the amount of available space on the rooftop
- for a green wall or facade, consider the number and size of windows and the useable area

Green roofs are more difficult to construct on slopes of more than 15 degrees (Department of Environment and Primary Industries, 2104).

Structural loading

When retrofitting a green roof, wall or facade, establish early whether the structure is strong enough to carry the additional weight, or whether modifications to the structure will be required. Engage a structural engineer to identify the structural load-bearing capacity of the building to support a green roof, wall or facade. The weight of mature plants and saturated soil (or growing media) must be included in the structural assessment.

Depending on the size, slope and structural capacity of the roof, and project budget, there may be an opportunity to integrate solar panels as part of the green roof design.

c. Access

Assess how accessible the site is. For a green roof, the amount of access can determine which type of green roof is appropriate. If a roof is to be designed for people to use the space, it will need to be accessible by stairs or a lift, and meet health and safety legislation. It will also need pathways on the rooftop.

For a green wall or facade, access for construction and maintenance is a key consideration. The height and size of a green wall or facade may be determined by the space available for access during construction and for maintenance.

Access during construction

Identify temporary access routes and storage locations for:

- machinery
- deliveries
- materials

For a green wall sited along the edge of a footpath, access for passers-by needs to be maintained. For a green roof, consider how materials will be moved onto the roof.

Access for long-term maintenance

Green roofs, walls and facades require regular maintenance so long-term access is an important consideration. Maintenance is required for:

- plants
- irrigation systems
- structures
- drainage systems

Balustrades, cables, ladders and elevated work platforms may be required for maintenance staff, depending on the height, size and location of the green roof, wall or facade.

For a green wall or facade, access requirements depend on the proposed size and height. Maintenance could be from below or above. If the wall or facade is less than 4m high and accessible from the ground, a ladder can be used. For a green wall between 4m and 10m high and accessible from the ground, a temporary scaffold can

be used. When the wall is more than 10m high, a building maintenance unit (BMU) system, abseiling or cherry picker should be used (RICS, 2016). Access for window cleaning needs to be considered when designing a green wall or green facade.

See section 8 for more detailed information on maintenance.

d. Heritage

Review Council planning maps, in the relevant local environmental plan (LEP), to determine if the building is a heritage item or in a heritage conservation area. Speak to Council if your building is affected as there are some constraints associated with these properties and additional approvals may be required. The relevant Development Control Plan (DCP) provides guidance related to heritage. This differs depending on a number of factors including the location of the building and the specific character of the area. Proposals are assessed on a site by site basis based on an assessment of the heritage impact of the proposal and whether the proposal meets the relevant controls. A pre-DA meeting with Council is recommended as it will provide further advice.

Evaluate the existing structure of the building, which could be compromised by the proposed works. A green roof, wall or facade must not negatively impact the structural integrity of the building.

Green wall, Lilyfield.
(Source: Atlantis Aurora 2016)

e. Water

Green roofs, walls and facades are water sensitive urban design (WSUD) technologies and help manage water on and around the site, especially if there is an issue with localised flooding.

Estimate:
- the amount of rainfall that lands on the site and drains onto it
- the typical length of rainfall events
- the pitch of the roof (which determines the speed which water collects)
- the location of drains and their capacity (dimensions and diameters)

Refer to Council's Flood Control Lot mapping to determine if the site is in a flood affected area. Identify if the site is affected by localised flooding and to what extent.

For properties in the former Marrickville LGA:
- refer Marrickville DCP Section 2.17 Water Sensitive Urban Design for more information

For properties in the former Leichhardt LGA:
- refer Leichhardt DCP Appendix E – Water Guidelines for more information

For properties in the former Ashfield LGA:
- refer Ashfield DCP Chapter A Part 15 Stormwater Management for more information

Green roofs, walls and facades can help manage localised flooding. They slow down water in storm events and reduce the impact on the network of stomwater pits and pipes. They do this by capturing and storing rain water and then slowly releasing it into the stormwater network over time.

Drainage

For an existing structure, assess the existing drainage capacity on the roof or wall by identifying:
- the type of roof drain that has been installed
- the condition of the existing roof membrane. Any damage must be repaired before retrofitting the roof with a green roof.
- if there are any potential impediments for water

Types of existing drainage include box and eave gutters, waterspouts and roof outlets. Buildings with parapets and other potential impediments could cause water to build up behind them and cause additional loading on a structure not designed to accommodate such loads (RICS, 2016).

Irrigation

Green roofs, walls and facades typically require irrigation. Water is required for the plants but needs to be managed carefully so that it does not cause damage to structures.

Consider irrigation requirements by identifying:
- any existing water supplies nearby
- whether rainwater or another water source can be used to irrigate the plants
- the expected volume and distribution of rainfall and if this would be sufficient for the proposed plants
- if there is space to store water on-site in water tanks

Avoid or minimise the use of potable (drinking) water for irrigation. Using water from greywater or rainwater tanks is a sustainable way to irrigate green roofs, walls and facades. Using greywater to irrigate green walls also cleans the water at the same time (Prodanovic et al, 2019).

f. Biodiversity

Consider any vegetation nearby and what sort of habitat a green roof, wall or facade in this location can provide. Green walls, roofs and facades can help flora and fauna move throughout the urban landscape, by creating habitat corridors and stepping stones.

Review Council plans and policies to check if the site is within or close to a wildlife corridor, priority biodiversity site or important habitat site. For example, the GreenWay, Cooks River wildlife corridor and Parramatta River corridor are important areas for biodiversity in the Inner West. Refer to Ashfield, Leichhardt and Marrickville biodiversity strategies, LEPs and DCPs for further information. Wildlife corridors are mapped in the Marrickville Council LEP and DCP. Any work on lots in these zones have additional requirements.

Consider targetting specific animals and designing habitat opportunities into the green roof, wall or facade. For example, there are threatened bandicoot and bat species which live in the Inner West LGA. Including elements such as artificial nest boxes, bat boxes, dense shrubs and water sources can help encourage these species to live in the inner west.

Flora

Identify:

- native Australian plants which grow in the area. Use these species to enhance urban biodiversity and provide habitat for local fauna.

Fauna

Identify fauna species that:

- live in or use the local area. Refer to the NSW Environment, Energy and Science's NSW Bionet Atlas, and the Atlas of Living Australia online mapping databases to identify local fauna which have been sighted in the area.

Site analysis checklist: Green Roof

This checklist is a summary of information required to complete a site analysis for a green roof. This will provide the background information to help design a green roof in the next phase of the project.

Microclimate: sun and shade	Notes
- How much sun and shade does the site receive?	
- Is there overshadowing from other buildings or vegetation?	
- What is the orientation of the roof?	
- How high is the building above ground level?	
Microclimate: wind	
- How windy is the site?	
- From which direction do the prevailing winds come from?	
Structure: size, slope and plant equipment	
- What is the size of the roof?	
- On an existing roof, what is the condition of the roof?	
- What is / will be the slope (or pitch) of the roof?	
- Is there / will there be equipment on the roof?	
Structure: structural loading	
- What is / will be the load-bearing capacity of the roof?	
- Is there an opportunity to include solar panels?	
Access	
- Is there access to the site?	
- How would the site be accessed during construction?	
- How would the roof be accessed for maintenance?	
Heritage	
- Is the building a heritage item or in a heritage conservation zone?	
Water: irrigation	
- Is there an existing water supply on the roof?	
- Is there potential to install a tank to provide water for irrigation?	
- Is there potential to use greywater for irrigation?	
Water: drainage	
- Where is the drainage and what is the capacity?	
- How much rain lands / will land on the roof?	
- Are there existing drainage issues on the roof?	
Biodiversity	
- Is the site in or near a wildlife corridor or priority biodiversity area?	
- What native fauna is living in the area?	
- What are the local native plants of the area?	
- What fauna or flora species need habitat?	

Example 1: Site analysis plan for a green roof

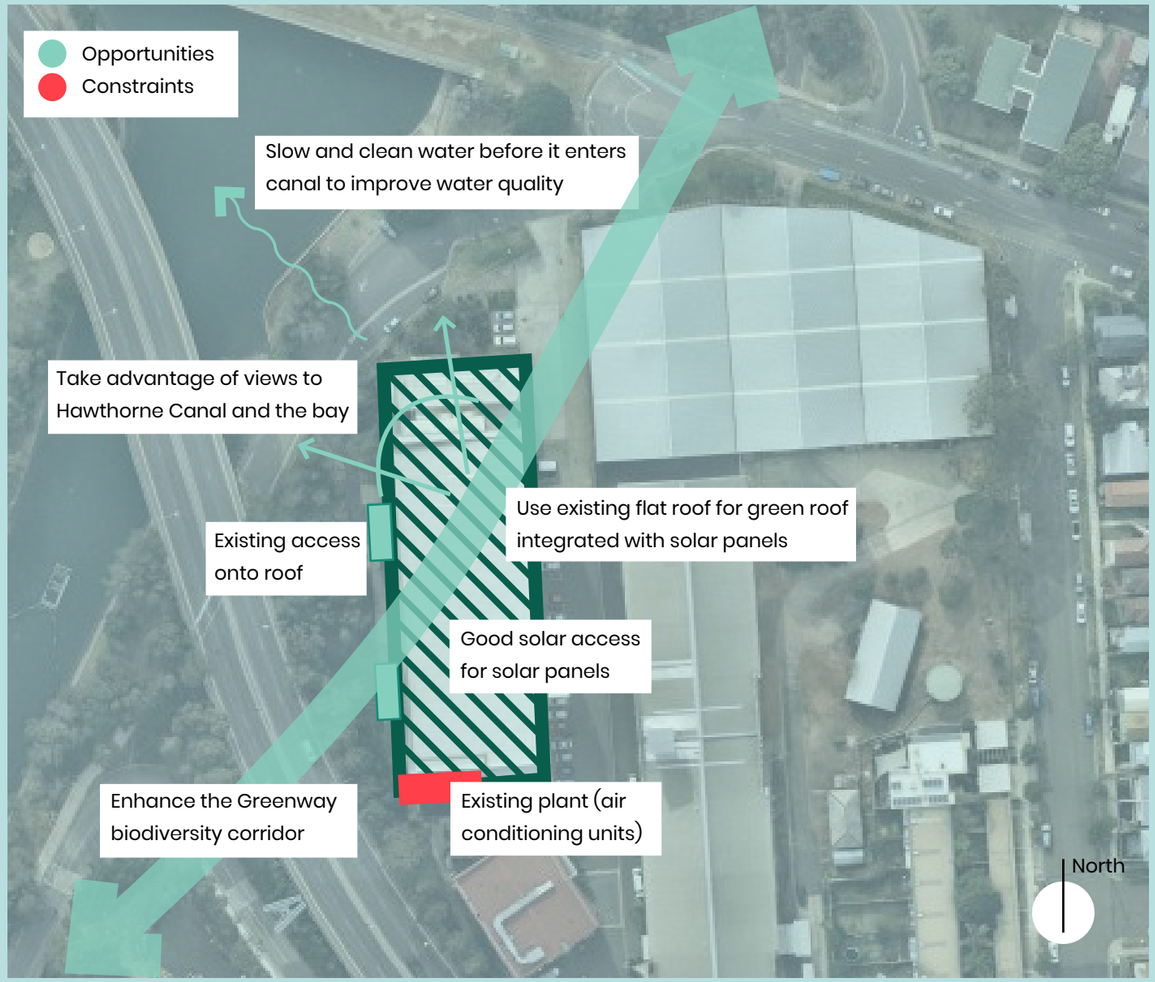
This analysis diagram illustrates the key findings from an example site. Developing the site analysis plan diagram will provide background information to help identify opportunities and constraints for the site.

Illustrative site analysis plan (not to scale) for a potential green roof site on an industrial building, using NearMaps aerial image as base.

Proposed green roof area

Example 1: Opportunities and constraints diagram

Develop an opportunities and constraints diagram based on the findings of the site analysis. This diagram will help summarise the site analysis and identify appropriate locations for a green roof on the site and the existing conditions.



Illustrative opportunities and constraints diagram for a potential green roof site, using NearMaps aerial image as base (not to scale).

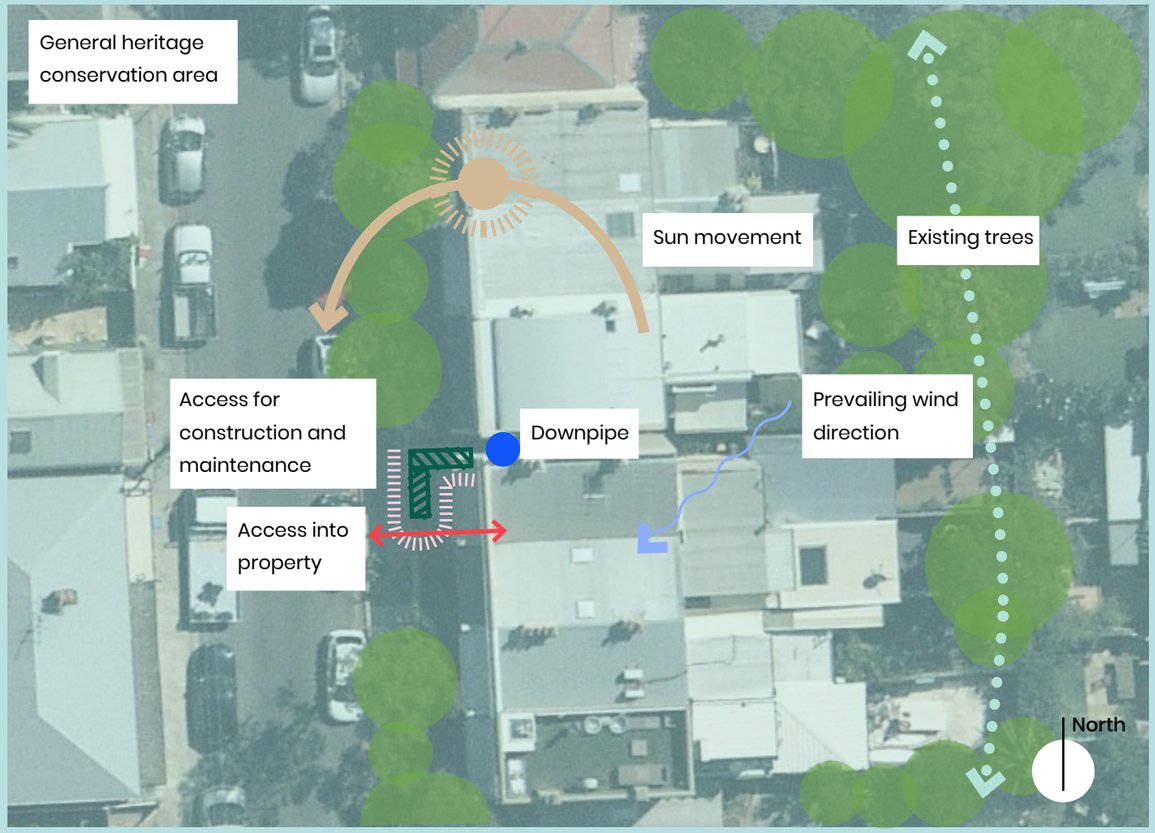
Site analysis checklist: Green wall or facade

This checklist is a summary of information required to complete a site analysis for a green wall or facade. This will provide the background information to help design a green wall or facade in the next phase of the project.

Microclimate: sun and shade	Notes
- How much sun and shade does the site receive?	
- Is there overshadowing from other buildings or vegetation?	
- What is the orientation of the wall?	
Microclimate: wind	
- How windy is the site?	
- From which direction do the prevailing winds come from?	
- Is there existing wind tunnelling in the area?	
Structure: size, slope and plant equipment	
- How high is the wall or structure?	
- For an existing wall or structure, what is its current condition?	
- Are there windows, downpipes or other elements on the wall?	
Structure: structural loading	
- What is / will be the load-bearing capacity of the wall or structure?	
- What is the stability of the ground to support a green wall or facade?	
- Is there an opportunity to include solar panels?	
Access	
- Is there access to the wall from the ground?	
- Where would access be during construction?	
- How would the wall or facade be accessed for maintenance?	
Heritage	
- Is the building a heritage item or in a heritage conservation zone?	
Water: irrigation	
- Is there an existing water supply nearby?	
- Is there potential to install a tank to provide water for irrigation?	
- Is there potential to use greywater for irrigation?	
Water: drainage	
- Is there existing drainage on the ground below the wall?	
- Where is the drainage and what is the capacity?	
Biodiversity	
- Is the site in or near a wildlife corridor or priority biodiversity area?	
- What native fauna is living in the area?	
- What are the local native plants of the area?	
- What fauna or flora species need habitat?	

Example 2: Site analysis plan for a residential green wall

This analysis diagram illustrates the key findings from the site analysis. Developing this diagram will provide background information to help identify opportunities and constraints for the site.



Illustrative site analysis plan (not to scale) for a potential green wall, using NearMaps aerial image as base.

Proposed green wall location

Example 2: Opportunities and constraints diagram

Develop an opportunities and constraints diagram based on the site analysis. This diagram will summarise the site analysis and identify appropriate locations for a green wall or facade based on the site and the existing conditions.

Illustrative opportunities and constraints diagram (not to scale) for a potential green wall, using NearMaps aerial image as base.

Green roof, Forest Lodge Eco House.
(Source: Khierim, C. via Greenroofs.com, 2014)

6. Planning and Design

This section provides an overview of the planning and design phase for green roofs, walls and facades. It outlines key design considerations to ensure a successful project.

a. Specialist consultant advice

The design and documentation of green roofs, walls and facades requires the services of appropriately qualified and experienced professionals. Depending on the size of the project, the engagement of a project manager, architect or landscape architect specialising in this area is highly recommended. This consultant will coordinate other disciplines that may be needed, including structural and hydraulic engineers.

This professional may require the services of some or all of the following professionals to be involved in the design of the project:

- Project manager: oversees the project, including the program and budget
- Landscape architect: plan, design and document the layout, planting design and species selection
- Architect: if the green roof, wall or facade is part of a new building an architect will be involved in integrating the design with the building
- Structural engineer: determine load-bearing capacity of an existing roof or wall, design the new roof and any new structures to tolerate rainfall and wind exposure specific to the site
- Mechanical engineer: calculate heating and cooling implications with the addition of a green roof, wall or facade and its integration with existing and new rooftop mechanical equipment
- Hydraulic engineer: design of irrigation and drainage system, integration into existing drainage system where necessary, and tanks and pumps
- Horticulturist: plant species selection and advice
- Growing media manufacturers: selection of appropriate growing media
- Waterproofing manufacturer: evaluation of the existing roof, wall or structure and selection of appropriate waterproofing

The benefit of using consultants with demonstrated experience in green roofs and walls will generally result in a smoother and more straight-forward design, approval and construction process. The Green Roofs Australasia website (https://greenroofsaustralasia.com.au/) has an industry directory which covers some suppliers for green roofs, walls and facades. The Australian Institute of Landscape Architects (http://www.aila.org.au/) and the LNA Masters Landscapers Association websites (https://www.landscapenswact.com.au/) provide lists of registered landscape architects and contractors.

For smaller projects, a supplier of green roofs, walls and facades may provide multiple services which can make the project more simple.

> Council holds free Water Sensitive Design In Your Backyard workshops throughout the year to provide expert advice and help residents implement water sensitive techniques including green roofs and walls on their property.
> Contact Council for more information on -
> P: 9392 5000
> E: urbanecology@innerwest.nsw.gov.au

b. Local planning requirements and building standards

Ensure your green roof, wall or facade complies with Inner West council planning requirements. Review the statutory development control plans (DCPs) and local environment plans (LEPs) for any relevant requirements for your site. Until consolidated, Inner West Council planning documents are finalised, these can be found in Marrickville Council, Leichhardt Council or Ashfield Council documents. Part C1.21 of the Leichhardt Council DCP provides guidance for green roofs and green living walls.

Depending on the size and complexity of the project, constructing a green roof, wall or facade may require a Development Application (DA). Speak to one of Council's Planning Advisory Officers at a Customer Service Centre to check if this is a requirement for your project. Phone 9392 5000 to make a booking.

Any new green roof, wall or facade project must comply with Council's requirements relating to:

- disposal of rubbish and access for waste collection
- on site water management and drainage
- access for emergency services

Refer Section 7.a. WHS and Environmental Controls and Management for more informaton.

c. Design objectives

Determine the design objectives for the project. This will guide how the project is planned, designed and constructed. The many possible design objectives depend on the planning requirements, budget, and the clients requirements and expectations. Identifying the key reasons for completing the project will ensure that the budget is allocated appropriately.

Objectives could include:

- Enhancing urban biodiversity
- Improving the quality of water entering the stormwater system
- Decreasing the quantity of water entering the stormwater system
- Improving thermal efficiency and provide insulation
- Reducing the urban heat island effect
- Reducing noise pollution
- Absorbing airborne pollution and filtering the air
- Providing recreation and amenity opportunities
- Providing opportunities for urban agriculture
- Enhancing conditions for solar photo-voltaic (PV) panels
- Screening, providing privacy and improving views

Key design considerations include the size of the building or wall, age (if retrofitting) and structural capacity of the building, budget, exposure to wind and sun, heritage status, access, views and maintenance requirements. These will have been identified in the site analysis phase. Review the site anaylsis checklist, and the site anlysis and opportunities and constraints diagrams, which were prepared during the site analysis phase.

When designing a green roof, the building must be able to support the estimated dead load, live load, and transient loads related to the green roof. Dead load is the weight of the entire green roof, including plants

and the water when the growth media is saturated. Live load refers to the weight of a green roof, factoring in variables which change over time. This typically includes the weight of excess water and people visiting the green roof (Velazquez, 2010). Transient loads are moving, rolling or short-term loads, including wind and seismic activity (Department of Environment and Primary Industries, 2014).

Also consider the impact of a green roof on neighbours privacy and views.

d. Building rating schemes

A number of building rating schemes can be used to assess the environmental sustainability of buildings. These schemes can be a way of marketing a building or development, and setting it apart from other developments in the area. For example:

- Green Star. The Design and As Built rating tool - land use and ecology category - awards points if the building enhances the ecological value of the site and reduces its impact on the urban heat island effect. The Green Star Performance Ecological Value credit rewards projects that improve the ecological value of the site.
- The Living Building Challenge. Green walls, roofs and facades can help reach requirements for urban agriculture, on-site water management, beauty and energy requirements.
- The National Australian Built Environment Rating Scheme (NABERS). NABERS uses a six star scale to rate the environmental performance of buildings, and has rating tools for energy efficiency, water efficiency, waste management and indoor environmental quality. It is mandatory during the sale or lease of offices with floor space of more than 2000sqm.
- NatHERS (Nationwide House Energy Rating Scheme). The NatHERS star rating system (out of ten) rates the energy efficiency of a home based on its design. It is administered by the Commonwealth Government.

Other international rating tools are sometimes used in Australia. These include the Leadership in Energy and Environmental Design (LEED) used in the US and elsewhere, and the Building Research Establishment Environmental Assessment Method (BREEAM) and One Planet Living, both developed in the UK.

e. Planning for drainage and irrigation

Drainage and irrigation must be planned carefully to ensure that the green roof, wall or facade does not compromise the structural integrity of the building.

Drainage

Proper drainage will ensure that water does not pond and that plants do not get waterlogged. Water must be drained away effectively. Drainage systems must also be able to cater for extreme rainfall events or on site flooding.

In the case of a green roof retrofit project, drainage must be designed so that water does not become trapped between the existing roof and the new green roof. Plan for multiple water drainage paths so that if one gets blocked, there is still sufficient capacity to remove water. This will also help in extreme weather events.

Typically, an architect or builder is responsible for waterproofing the external surface of the building. However, with a green roof or wall there are other factors to consider with the waterproofing layer so engaging a suitably qualified professional to provide advice is strongly encouraged (Fifth Creek Studio, 2014).

Irrigation

Irrigation is essential for the success of most green roofs, walls and facades. Irrigation requirements depend on the amount of rain, sun and wind the site receives, and the type of plants on the green roof, wall or facade. Irrigation also helps to minimise any fire risk on green roofs, walls or facades.

Green wall products often have built-in irrigation which uses drip line irrigations systems. Green walls can be water intensive, though new designs are being developed to minimise water requirements, such as installing intermediary drainage catchment trays across the face of the wall (Junglefy, 2014).

The planning and design of any irrigation system should investigate using non-potable water for irrigation. An on-site water tank can be used to collect water to irrigate the plants and reduce reliance on drinking water supplies.

f. Planning for wind and fire safety

Wind and fire safety are important considerations when planning and designing a green roof, wall or facade.

Wind

Wind is an important consideration when planning a green roof, wall or facade. Green walls and facades should be planned and designed to reduce any risks associated with wind. Footings and fixings need to be

Green roof, MCentral Building Sydney.
(Source: Green Roof – 38 Westbury Street, St Kilda East, 2020)

designed to withstand wind conditions for each site. While it is more of a consideration for green roofs, green walls and facades should also be planned with wind in mind.

For intensive green roofs which have trees or other structures consider how they might need to be secured to the rooftop. Trees may need to be anchored to prevent 'wind-throw' (Department of Environment and Primary Industries, 2014). Various anchoring systems can be utilised. They typically use anchor straps to secure the root ball or tree trunk to a weight which is buried under the surface of the soil. In a high wind environment, also consider how furniture can be secured to the rooftop. Furniture may need to be fixed to the roof rather than using moveable furniture.

In a high wind environment, wind erosion of growing media can be an issue immediately following installation of a green roof. Wind erosion control systems such as erosion blankets can be anchored to the surface to prevent soil or mulch being displaced (Green Roof Solutions, 2018).

Fire resistance

Green roofs, like any vegetation-covered surface, need to be designed to provide the necessary resistance to the external spread of fire, even when subjected to prolonged periods of drought. It has been suggested that green roofs and walls may be a fire hazard but as long as the green roof or wall is kept moist (normally the case in order to keep the plants alive) it is likely to be resistant to ignition (Department for Communities and Local Government, 2018). There is evidence suggesting that green roofs can help slow the spread of fire to and from the building through the roof, particularly where the growing medium is saturated.

Plants can present a fire hazard if they get dry. Certain plants should be avoided from use on rooftops for fire safety reasons. They include plants that are highly flammable, plants that develop large root systems and have high biomass, and plants that are excessively thirsty (Hui, 2011). Plants with high levels of volatile oils or resins should be also avoided, especially in areas prone to bushfires. Succulent plants are recommended. They retain water within their structure and will enhance the roofs fire performance (Tidwell and Murphy, 2010). Overhanging or nearby vegetation could also contribute to a fire risk on site. Ensure that any existing planting does not cause a fire risk.

The integration of 'fire breaks' at regular intervals across the roof, at the roof perimeter, and around all roof penetrations is recommended. Fire breaks typically consist of non-vegetated strips, 500mm wide, made of ballast with a diameter of 20-50mm, or concrete pavers (Department for Communities and Local Government, 2018).

Ensure compliance with fire safety regulations, including fire-fighting equipment and fire resistance of materials used. For example, on a green roof consider the type of mulch to be used. Organic mulch can contribute to fire risk in hot, dry conditions and should be avoided in high risk locations. Gravel mulch is a better solution.

g. Planning for access and maintenance

Access and maintenance requirements will differ between green roofs, walls and facades.

Access

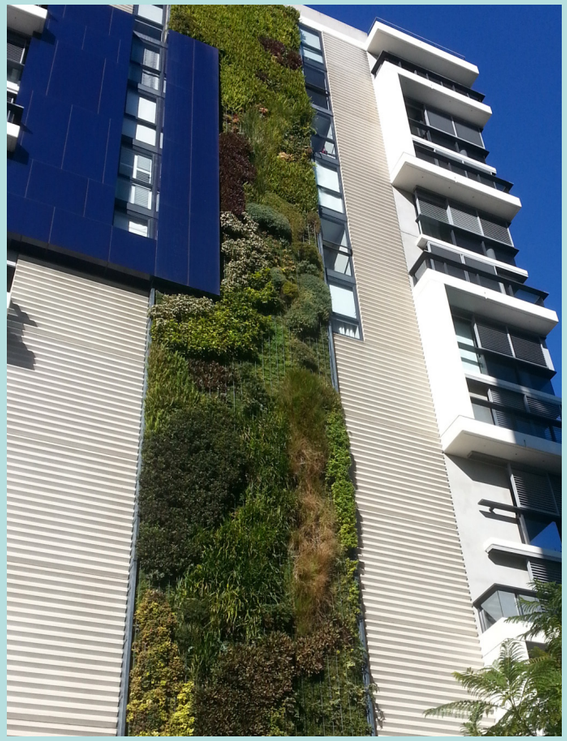
Access to the green roof, wall or facade must be carefully planned to ensure that access is available where required and that it is in an appropriate location.

For green roofs, access onto the roof typically requires stairs or a lift. Access requirements vary depending on the design objective, and the type of green roof (intensive or extensive). Intensive green roofs require more access that extensive green roofs. Intensive green roofs are typically designed for amenity and passive recreation. They have seating and gathering areas, and perhaps a BBQ, pergola and kitchen garden. Consider how people will move through the space. Paths on the rooftop provide access to different areas. For extensive roofs, access is usually only required for maintenance.

For green walls and facades, access is only required for maintenance.

Maintenance

Design green roofs, walls and facades to ensure that the project can be easily maintained. A maintenance plan and budget should be developed during the design phase of the project. Maintenance requirements will depend on the type of green wall, roof or facade and will vary depending on the type of vegetation and irrigation, the use of the wall, roof or façade, and aesthetic preferences. Intensive green roofs typically require more maintenance because they have more plants. Similar



Green wall, Trio apartments Camperdown

to any garden, it should include watering, fertilising, pest control, pruning and replanting.

Any irrigation system and/or waterproofing membrane should be inspected regularly to make sure there are no leaks. Building owners and property managers must understand and be committed to these maintenance requirements. Consider the skills, resources and equipment that will be required, and design the green roof, wall or facade accordingly.

For green walls and facades on multistorey buildings, maintenance may require equipment such as forklifts, elevated platforms and industrial abseiling systems. Consider who will be responsible for maintenance and their capacity. A green roof, wall or facade contractor is best suited to providing on-going maintenance. Many installers include maintenance services for the first year which can be helpful during plant establishment. Costs associated with the maintenance should be made clear up-front. Plan how materials will be brought onto and removed from the site as part of the maintenance.

h. Co-locating sustainable energy technologies

Green roofs, walls and facades are opportunities to integrate sustainable energy technologies onto a building or other structure. A range of technologies such as solar photovoltaic (PV) cells, solar water heating and wind power can be included.

Solar photovoltaic (PV) cells

Green roofs are a great place to install solar PV cells. When located on green roofs, PV cells are more efficient than when they are installed on a traditional rooftop. Cooler temperatures generated by the green roof provide a better environment for solar PVs to generate solar power (McGee, 2013). Cooler conditions also improve the longevity of the cells because constant high temperatures can reduce the long-term stability of the cells.

Inner West Council is working with UNSW and the Australian Photovoltaic Institute to support residents to install solar panels. SunSPoT is an online 'solar potential tool' which estimates the potential for electricity generation and the amount of money which could be saved by installing a solar system. Council also provides detailed advice on solar installation and systems, and obligation-free quotes from vetted, reliable installers who claim any and all rebates on their customers' behalf.

Solar Hot Water

Solar hot water units installed on green roofs take advantage of Australia's supply of sunshine and use solar energy to heat water. Solar hot water units reduce electricity bills and greenhouse emissions.

There are two types of solar water heating systems:
- active systems: include circulating pumps and controls
- passive systems: no pumps or controls

Key components of solar water heating systems are the hot water storage tank and solar collector. Depending on the site, the tank can be located on the roof or on the ground. There are many products on the market, so it is important to research the options and choose the most suitable product.

For more information refer to http://www.energyrating.gov.au/products/water-heaters/solar-water-heaters

Wind power

Rooftops can be windy, especially on tall buildings. This provides a great opportunity to locate wind turbines on a roof to generate additional energy for the building. Typically, the higher the turbine and the further away from obstructions such as trees and buildings, the greater the output of energy. When co-locating wind turbines and green roofs, consider the location of the wind turbines to ensure clear access and safe movement for people using the rooftop. Engage a specialist consultant to advise on the suitability of wind power for the specific site and the design (City of Sydney, 2010).

i. Cost considerations

The cost of green roofs, walls and facades varies depending on the size, type and location. Green walls and green facades can be installed quite simply. They can be made from simple, cost efficient materials. There will be costs for design, construction and maintenance, and these will vary depending on the project.

Costs will depend on:
- type of green roof, wall or facade
- size and height above ground level
- type of structure and if reinforcing is required
- location of the site and available access
- slope of roof
- depth of substrate
- material selection
- size of plants and if anchoring is required

Pixel Building, Melbourne by deciBel(Architecture))) (Source: studio505, 2010)

- inclusion of sustainable energy technology
- existing services including water
- ongoing maintenance requirements

Green roofs and walls installed as part of a new building are typically much cheaper than retrofitting an existing building. This is because the structural load-bearing capacity requirements can be integrated into the design from the outset.

Ongoing maintenance is required and should be budgeted for. Ongoing maintenance costs are approximately 2 - 12% per year of the installation costs (RICS, 2016). These costs could also include the cost of equipment required to maintain the site, such as elevated work platforms.

j. Recyclable materials

It is possible to specify recyclable and recycled materials for most components of a green roof or wall. For example, more than 94 per cent of the materials and media can be reclaimed from waste destined for landfill. These include the growing media, metals and fabrics. Careful specification will maximise use of recyclable materials.

When using growing media with recycled content, make sure they do not include plastics, including expanded polystyrene, to avoid them blowing away and entering drains, rivers and harbours (RICS, 2016).

k. Habitat creation

Green roofs, walls and facades provide additional habitat and increase biodiversity in the urban environment, where habitat is often limited.

Green roofs

Green roofs can provide a range of habitat opportunities. Three design factors have been linked to biodiverse green roofs:

1. variation in depth, topography and composition of growing media
2. vegetation diversity
3. structures to create niche spaces for organisms

To increase rooftop biodiversity, integrate the following into the design:

- increase the depth of growing media
- vary the composition (structure) of growing media
- provide topographic variety
- provide a range of microclimates
- diversify the plant species
- provide perching habitat, such as rocks, logs, branches and constructed elements
- provide nesting opportunities, such as bird houses, insect hotels and habitat boxes
- provide water source(s), such as basins, ponds, naturally pitted rocks and bird baths

(City of Toronto, 2013)

Green walls and facades

For green walls and facades, bee hives, bee bundles, bird boxes, insect hotels and habitat boxes can be designed into the structure. Using a diverse range of plants also increases biodiversity.

l. Plant selection

Choose plants based on stormwater management objectives, biodiversity objectives, aesthetic requirements, root zone requirements and water requirements. Review the existing microclimate and choose plants suited to the site conditions and the type of green roof, wall or facade.

Generally, the plants have to grow in tough conditions, especially on green roofs. They are subject to high levels of wind, intensive sunlight, temperature extremes, extensive periods of drought (if not irrigated) and often excessive shading from adjacent buildings. Drought tolerant plants are a good choice.

Green roof plants

An intensive green roof is able to support larger plants as the soil depth is greater. This includes trees, depending on the exact depth of the soil. When specifying trees for green roofs it is important to consider the volume of soil required to ensure healthy growth of the tree. Table 1 on the following page shows standard green roof soil volumes for different types of plants.

Green wall and facade plants

For a green wall, plant species may need to vary from the bottom of the wall to the top as the levels of light, water, air circulation and humidity can vary.

It is recommended that the plants selected for each project all have the same growing requirements, e.g. soil, drainage and water requirements.

Aim to select local native plants. Council encourages the use of local native plants for green walls, roofs and facades to protect and increase local biodiversity. These plants are suited to the local climate and conditions and are more resilient to climate change.

Laneway House, Newtown
(Source: Jon Jacka, 2018)

They can be ordered and purchased from community nurseries in the Inner West LGA - Marrickville Community Native Nursery or Rozelle Bay Community Native Nursery.

Suggested plant lists are also available online which include native and non native species.

Results of a study in northern Sydney show the following species perform well in a shallow, non-irrigated green roof environment:

- Blue flax lily (*Dianella caerulea*)
- Climbing guinea flower (*Hibbertia scandens*)
- Spiny mat rush (*Lomandra longifolia*)

(Australian Research Institute for Environment & Sustainability, n.d.)

Plant type	Definition	Soil volume	Soil depth	Soil area
Large trees	12-18m high, up to 16m crown spread at maturity	150m^3	1, 000mm	10m x 10m or equivalent
Medium trees	8-12m high, up to 8m crown spread at maturity	35m^3	900mm	6m x 6m or equivalent
Small trees	6-8m high, up to 4m crown spread at maturity	9m^3	800mm	3m x 3m or equivalent
Shrubs			500mm	
Groundcover			300mm	
Turf			150mm	

Table 1. Minimum soil standards for plant types and sizes
(Adapted from the Apartment Design Guide, 2015, p.116)

Note: These soils standards have been calculated assuming fortnightly irrigation. Any subsurface drainage requirements are in addition to the minimum soil depths in Table 1.

The species lists on the following pages are based on the hardiness of the species and suitability for a particular roof or wall application. Please not that the performance of these species has not specifically been tested on green roofs and walls.

Some especially hardy local native are:

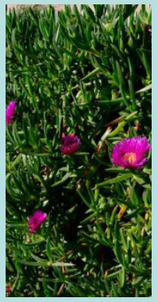
Common Name	Botanic Name
Trees	
Dwarf Apple	*Angophora hispida*
Coast Banksia	*Banksia integrifolia*
Old Man Banksia	*Banksia serrata*
Crimson Bottlebrush	*Callistemon citrinus*
Shrubs	
Native Fuschia	*Correa reflexa*
Native Indigo	*Indigofera australis*
Kunzea	*Kunzea ambigua*
Thyme-leaf Honey-myrtle	*Melaleuca thymifolia*
Grasses	
Black-anther Flax-Lily	*Dianella revoluta*
Mat Rush	*Lomandra spp.*
Blue Tussock Grass	*Poa poiformis*
Slender Wallaby Grass	*Rhytodisperma racemosa*
Kangaroo Grass	*Themeda triandra*
Groundcovers and climbers	
Pigface	*Caprobrotus glaucescens*
Kidney Weed	*Dichondra repens*
Purple Twining Pea	*Hardenbergia violacea*
Dusky Coral Pea	*Kennedia rubicunda*
Wonga Wonga Vine	*Pandorea pandorana*
Coastal geranium	*Pelargonium australe*
Fairy Fan flower	*Scaevola aemula*
Native Sarsparilla	*Smilax glyciphylla*
Native Violet	*Violacea hederacea*


Old Man Banksia (*Banksia serrata*)


Dwarf Apple (*Angophora hispida*)


Coast Banksia (*Banksia integrifolia*)


Thyme-leaf Honey-myrtle (*Melaleuca thymifolia*)


Pigface (*Caprobrotus glaucescens*)


Purple Twining Pea (*Hardenbergia violacea*)


Blue flax lily (*Dianella caerulea*)

Source: Refer image list in references

Suggested species list: Green roof

This list of suggested local inner west species can be used on an extensive green roof. Suggested plant lists are also available online which include native and non native species.

Common Name	Botanic Name	Features (flowers, bird attracting, pollinator species)
Grasses		
Bulbine Lily	*Bulbine bulbosa*	Yellow flowers
Blue flax lily	*Dianella caerulea*	Purple flowers and berries, attracts birds
Knobby Club-rush	*Ficinia nodosa*	
Native Flax	*Linum marginale*	
Spiny mat rush	*Lomandra longifolia*	
Blue Tussock Grass	*Poa poiformis*	
Slender Wallaby Grass	*Rytidosperma racemosum*	
Bristly Wallaby Grass	*Rytidosperma setacea*	
Hairy Spinefex	*Spinifex sericeus*	
Trigger Plant	*Stylidium graminifolium*	Pink flowers attract insects and birds
Kangaroo Grass	*Themeda triandra*	
Succulent Ground Creepers		
Pigface	*Carpobrotus glaucescens*	Bright pink flowers, provides fleshy fruit for birds
Warrigal Greens	*Tetragonia tetragonioides*	Edible leaves
Groundcovers		
Native Cranberry	*Astroloma humifusum*	Small red flowers
Bossiaea	*Bossiaea prostrata*	Small yellow and brown flowers
Common Everlasting	*Chrysocephalum apiculatum*	Yellow flowers
Nodding Saltbush	*Einadia nutans*	Red berries, attracts birds, lizards and insects
Kidney Weed	*Dichondra repens*	Tiny white flowers
Love Creeper	*Glycine clandestina*	White flowers, food plant for caterpillars
Guinea Flower	*Hibbertia diffusa*	Yellow flowers
Guinea Flower	*Hibbertia serpyllifolia*	Yellow flowers
n/a	*Hydrocotyle peduncularis*	
Creeping Boobiala	*Myoporum parvifolium*	White or pink flowers
Wild Geranium	*Pelargonium inodorum*	Tiny pink flowers
Rice Flower	*Pimelea linifolia*	White flowers
Pomax	*Pomax umbellata*	
Poranthera	*Poranthera microphylla*	Tiny white flowers
White Root	*Pratia purpurascens*	White to pale purple flowers
Fairy Fan-flower	*Scaevola aemula*	Purple flowers
Small Fan Flower	*Scaevola albida*	White flowers
Dune Fan Flower	*Scaevola calendulacea*	Blue flowers
Rough Groundsel	*Senecio hispidulus*	
Slender Stackhousia	*Stackhousia viminea*	Yellowish/red flowers
Speedwell	*Veronica plebeia*	Small mauve flowers
Native Bluebell	*Wahlenbergia gracilis*	Small mauve flowers
Woolly Xanthosia	*Xanthosia pilosa*	Tiny pale yellow flowers
Climbers		
Climbing guinea flower	*Hibbertia scandens*	Yellow flowers

Trees and shrubs are for intensive green roofs as they have deeper layer of soil.

Common Name	Botanic Name	Features (flowers, bird attracting, pollinator species)
Trees		
Dwarf Apple	*Angophora hispida*	Cream flowers attracts birds and insects
Coast Banksia	*Banksia integrifolia*	Large yellow flowers attract bees, nectar and seed eating
Old Man Banksia	*Banksia serrata*	birds, butterflies, other insects and mammals
Crimson Bottlebrush	*Callistemon citrinus*	Red flowers, attacts insects and birds
Prickly-leaved Paperbark	*Melaleuca nodosa*	Cream flowers
Water Gum	*Tristaniopsis laurina*	Tiny yellow flowers
Shrubs		
Prickly Moses	*Acacia ulicifolia*	Cream flowers
Hair-pin Banksia	*Banksia spinulosa*	Yellow or orange flowers, attracts bees, nectar and seed eating birds and mammals
White Correa	*Correa alba*	White flowers, attracts nectar eating birds and other insects
Native Fuchsia	*Correa reflexa*	Red and yellow flowers
Hop bush	*Dodonaea triquetra*	Dark red seed capsules
Prostrate Kunzea	*Kunzea ambigua*	Small white flowers, attracts native insects, butterflies, and nectar eating birds
Native Indigo	*Indigofera australis*	Purple flowers, provides good nectar and food source for butterflies, bees and other insects
Paperbark Tea-tree	*Leptospermum trinervium*	White small flowers
Thyme-leaf Honey-myrtle	*Melaleuca thymifolia*	Purple flowers attract nectar loving insects and birds
Saloop	*Einadia hastata*	Small yellow flowers with small red berries, butterfly habitat
Austral Stork's-bill	*Pelargonium australe*	Pale pink flowers, attracts bees, butterflies and other insects
Sea-berry Saltbush	*Rhagodia candolleana*	Edible dark red berries attract birds, provides refuge for small birds, lizards and small mammals
Grasses		
Barbed Wire Grass	*Cymbopogon refractus*	
Black-anther Flax-Lily	*Dianella revoluta*	Purple flowers and berries, attracts birds
Longhair Plume Grass	*Dichelachne crinita*	
Mat Rush	*Lomandra spp.*	
Wallaby Grass	*Rytidosperma tenuis*	
Kangaroo Grass	*Themeda triandra*	
Groundcovers		
Native Cranberry	*Astroloma humifusum*	Small red flowers
Kidney Weed	*Dichondra repens*	Tiny white flowers
Love Creeper	*Glycine clandestine*	White flowers, food plant for caterpillars
Guinea Flower	*Hibbertia diffusa*	Yellow flowers
Wild Geranium	*Pelargonium inodorum*	Deep pink flowers
Rice Flower	*Pimelea linifolia*	White flowers
Pomax	*Pomax umbellata*	
Poranthera	*Poranthera microphylla*	Tiny white flowers
White Root	*Pratia purpurascens*	White to pale purple flowers
Rough Groundsel	*Senecio hispidulus*	
Slender Stackhousia	*Stackhousia viminea*	Yellowish/red flowers
Trigger Plant	*Stylidium graminifolium*	Pink flowers, attract insects
Speedwell	*Veronica plebeia*	Small mauve flowers
Native Bluebell	*Wahlenbergia gracilis*	Small mauve flowers
Woolly Xanthosia	*Xanthosia pilosa*	Tiny pale yellow flowers
Ferns		
Lip Fern	*Cheilanthes sieberi*	
Bracken Fern	*Pteridium esculentum*	

Suggested species list: Green wall

This list of suggested local inner west species can be used for green walls. Suggested plant lists are also available online which include native and non native species.

Common Name	Botanic Name	Aspect	Features (flowers, bird attracting, pollinator species)
Small shrubs			
Coast Rosemary	*Westringia fruticosa*	North, south, east	Purple flowers
Grasses			
Blue Flax-lily	*Dianella sp.*	North, south, east	Purple flowers and berries, attracts birds
Mat Rush	*Lomandra spp.*	North, west, east	
Knobby Club Rush	*Ficinia nodosa*	North, south, east	
Groundcovers			
Kidney Weed	*Dichondra repens*	South, east	
Fishweed	*Einadia trigonos*	South, east	
Native violet	*Viola hederacea*	South	Purple flowers
Climbers			
Apple Berry	*Billardiera scandens*	North, south, east	Yellow flowers and fruit, nectar attracts honeyeaters
Native Grape	*Cissus hypoglauca*	South, east	Small yellow flowers, edible purple berries eaten by birds
Old Man's Beard	*Clematis aristata*	North, south, east	Cream flowers, seeds for birds
Old Man's Beard	*Clematis glycinoides*	North, south, east	Cream flowers, provides safe nesting sites for small native birds
Wombat Berry	*Eustrephus latifolius*	North, east	Pink or white flowers, orange berries, attracts seed eating birds
Purple Twining Pea	*Hardenbergia violacea*	North, east, west	Purple flowers
Guinea Flower	*Hibbertia scandens*	North, east, west	Yellow flowers, attracts bees, butterflies and lizards
Dusky Coral Pea	*Kennedia rubicunda*	North, east, west	Red flowers, nectar attracts birds
Wonga Wonga Vine	*Pandorea pandorana*	North, east, west	White flowers, attracts bees, butterflies and other insects
Native Raspberry	*Rubus parvifolius*	North, east, south	Deep pink with edible red berries, provides habitat and fruit
Native Sarsparilla	*Smilax glyciphylla*	South, east	Cream flowers and shiny black berries
Ferns			
Maidenhair Fern	*Adiantum aethiopicum*	South	
Birds Nest Fern	*Asplenium australasicum*	South	
Necklace Fern	*Asplenium flabellifolium*	South	
Gristle Fern	*Blechnum cartilegineum*	South	
Bungwall Fern	*Blechnum indicum*	South	
False Bracken Fern	*Calochlaena dubia*	South	
Mulga Fern	*Cheilanthes sieberi*	North	
Harsh Ground Fern	*Hypolepis muelleri*	South	
King Fern	*Todea barbara*	South	

Suggested species list: Green facade

This list of suggested local inner west species can be used for green facades. Suggested plant lists are also available online which include native and non native species.

Common Name	Botanic Name	Aspect	Features (flowers, bird attracting, pollinator species)
Climbers			
Apple Berry	*Billardiera scandens*	North, south, east	Yellow flowers and fruit, nectar attracts honeyeaters
Native Grape	*Cissus hypoglauca*	South, east	Small yellow flowers, edible purple berries eaten by birds
Old Man's Beard	*Clematis aristata*	North, south, east	Cream flowers, seeds for birds
Old Man's Beard	*Clematis glycinoides*	North, south, east	Cream flowers, provides safe nesting sites for small native birds
Wombat Berry	*Eustrephus latifolius*	North, east	Pink or white flowers, orange berries, attracts seed eating birds
Purple Twining Pea	*Hardenbergia violacea*	North, east, west	Purple flowers
Guinea Flower	*Hibbertia scandens*	North, east, west	Yellow flowers, attracts bees, butterflies and lizards
Dusky Coral Pea	*Kennedia rubicunda*	North, east, west	Red flowers, nectar attracts birds
Wonga Wonga Vine	*Pandorea pandorana*	North, east, west	White flowers, attracts bees, butterflies and other insects
Native Sarsparilla	*Smilax glyciphylla*	South, east	Cream flowers and shiny black berries

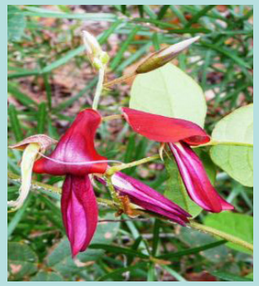
Wonga Wonga Vine (*Pandorea pandorana*)

Wombat berry (*Eustrephus latifolius*)

Old Man's Beard (*Clematis aristata*)

Guinea Flower (*Hibbertia scandens*)

Apple Berry (*Billardiera scandens*)



Dusky Coral Pea (*Kennedia rubicunda*)

Source: Refer image list in references

7. Construction

This chapter contains technical advice about constructing green roofs, walls and facades, including construction techniques and the types of materials required.

Before construction starts, put in place:
- work health and safety measures
- environmental controls and management

Work health and safety

New South Wales legislation
- Work Health and Safety Act 2011
- Work Health and Safety Regulation 2017

Green roofs, walls and facades present more risk as they can involve working at heights. All employers and businesses must comply with these laws to ensure the health and safety of workers. This WHS legislation is supported by SafeWork NSW's Compliance policy and prosecution guidelines, which supplements the national compliance and enforcement policy.

Before construction
As for any landscape project, work health and safety requirements apply. Risks and hazards during and after construction must be identified and designed out as far as possible during the concept and detailed design phases of the project. Remaining risks must be managed by constructing safety features on site, and worker training.

During construction
Thorough staff training and site induction must be done to minimise risks on the construction site. During construction, a range of safety features can be used, including barriers, fencing, railings, and safety anchors. Personal protective equipment (PPE) including safety clothing, helmets, gloves, dust masks or independently ventilated masks, goggles and safety glasses should be worn where necessary.

The location for delivery and storage of construction materials must be planned carefully. When selecting the site storage area, consider how materials are to be unloaded and moved across the site and if secure storage is needed. On particularly small urban sites, minimal storage may be available so it is critical to schedule the delivery of materials and ensure it fits in with the construction program.

Environmental Controls and Management

New South Wales legislation
Pollution from building and construction sites is regulated under the Protection of the Environment Operations Act 1997 (POEO Act). Under this Act it is an offence for anyone to let any substance other than rainwater enter a waterway including the stormwater system. Inner West Council and the Environment Protection Authority (EPA) can issue notices and penalties on building and construction sites to protect the environment.

Local government requirements
Council's requirements for environmental management on construction sites include:
- covering materials such as piles of soil or mulch so they do not blow away
- pollution control
- erosion and sediment control

A soil and water management plan (or sediment and erosion control plan) is required as part of a development application (DA), prior to Council issuing a construction certificate either at the DA stage or as a condition of consent.

Council is committed to using alternatives to chemicals such as pesticides and fertilisers, and strongly encourages all works within the LGA to do so as well. Examples of alternatives include Pyrethrum and natural remedies such as chilli, garlic or oil sprays.

Green roof in construction, Manly
(Source: Atlantis, 2008)

a. Green roofs

The following section details components for intensive and extensive green roofs.

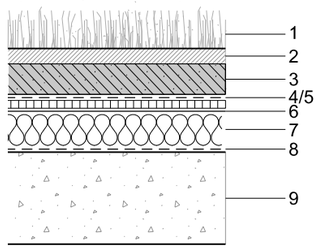
Green roofs are made up of a series of layers placed on top of the roof structure. While intensive and extensive green roofs have slightly different components, they typically include:

- waterproofing layer, including leak detention
- protection layer, such as root barrier
- drainage layer
- geofabric filter layer
- growing medium
- plants

Modular and blanket types of extensive green roofs, although uncommon in Australia at the moment (Hermy, 2018) also have benefits as they are less labour intensive to install as they come pre-grown.

Typical construction

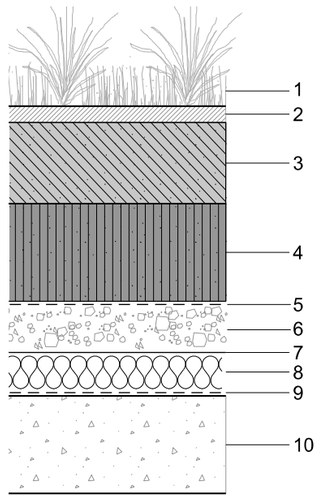
Extensive green roof typical detail



1 LOW PLANTING
2 MULCH 50mm
3 SOIL TYPE 1
4 GEOFABRIC FILTER LAYER
5 DRAINAGE CELL
6 WATER PROOFING SHEET MEMBRANE
7 ADDITIONAL INSULATION (OPTIONAL)
8 VAPOR SEAL
9 EXISTING REINFORCED CONCRETE ROOF

Section Scale 1:20

Intensive green roof typical detail



1 PLANTING
2 MULCH (50mm)
3 SOIL TYPE 1 (250 - 400mm)
4 SOIL TYPE 2 (300 - 600mm)
5 GEOFABRIC FILTER LAYER
6 20mm GRAVEL (NO FINES) LAYER
7 WATER PROOFING SHEET MEMBRANE
8 ADDITIONAL INSULATION (OPTIONAL)
9 VAPOR SEAL
10 EXISTING REINFORCED CONCRETE ROOF

Section Scale 1:20

Waterproofing

The first layer and a critical part of a green roof is waterproofing (numbers 6 and 7 in typical construction details on previous page). This is applied to the roof surface to prevent water getting into and damaging the building below. Waterproofing needs to be strong and flexible to expand and contract with any building movement.

Types

The three main types of waterproofing are:

1. Liquid applied treatments
2. Preformed sheets
3. Integrated systems

Liquid applied treatments

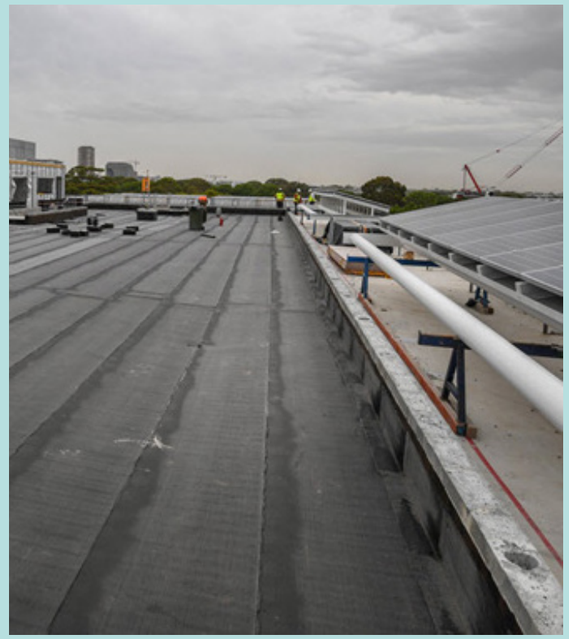
Liquid applied treatments are made from bitumen emulsions, modified bitumen, polymer cement systems, polyurethane, polyurethane modified acrylic, acrylic or two-part polyurethane hybrid elastomers. Some require mixing before application. It can be applied manually by brush, roller, spreader or spraying.

Preformed sheets

Preformed sheets are asphalt-based or a mix of thermosetting or thermoplastic polymers. They are sometimes referred to as ‘single-ply’ systems. They come in the form of rolls of sheets which are then unrolled and fixed onto the roof.

Integrated systems

Integrated systems can be used on new buildings where additives are included in the concrete mix to waterproof the concrete (O’Donoghue, 2016). This could also be used in pre-cast panels or tilt-up wall panels on external facades for green walls (City of Sydney, 2014).



Waterproofing on the Yerrabingin green roof, South Eveleigh
(Source: Outdoor Design Source, 2018)

Selection advice
Each type of waterproofing has its benefits, depending on the situation.

Liquid waterproofing can be better for roofs with lots of fixings such as light poles or ventilation. They are sprayed or rolled on which makes it easier to work around existing structures. They provide a seamless waterproofing solution which is easy to apply, can tolerate some degree of surface imperfection and is easily repaired. It is suitable for small roofs or roofs with a number of upstands, penetrations, corners or steep slopes.

Preformed waterproofing can be good for expansive green roofs on a gentle slope. Preformed waterproofing is usually fully bonded onto the roof surface. Joints between sheets are critical, and must be done perfectly to avoid leakage.

A specialist waterproofing consultant can advise on the most appropriate type of waterproofing. Selection will depend on:

- roof complexity and configuration
- proposed design of the green roof
- roof size
- purpose or activity of the building
- type of roof structure (existing or proposed)
- maintenance
- level of access needed for waterproofing
- climate
- the installer

Waterproofing should be installed by a waterproofing contractor. It must be tested after installation to ensure that it is watertight. It is best to have an independent leak detection specialist test the waterproofing.

Retrofitting
Existing waterproofing on a building which is being retrofitted with a green roof must be inspected by a specialist to ensure it is not leaking. All waterproofing must comply with the relevant Australian Standards. Refer Section 9 for further information.

Protection layer
It is important to protect the waterproofing layer from damage. This damage could be from physical damage or UV exposure. Root barriers are intended to prevent root damage to the waterproofing membrane. The root barrier is usually located above the drainage layer to prevent the root systems from choking up the drainage voids. This may be incorporated into the filter membrane layer.

Root barrier protection in green roofs can be part of the waterproofing layer except when this layer contains bitumen, asphalt or any organic material. Root penetration can cause micro-organisms to deteriorate the organic oil-based materials (Urbis Limited, 2007).

Drainage layer
The drainage layer drains excess water away from the saturated growing medium. It covers the whole roof and can also be designed to store water. The substrate should have a minimum slope of 1:100, preferably 1:40, sloping towards roof drainage points or gutters. All drainage fittings such as sumps and outlet points should have gravel aggregate surrounds for ease of maintenance and to reduce the potential of root infiltration.

The drainage layer can be composed of either a cell system or aggregate. It can be made of:

- Mineral aggregates: expanded slate and clay, lava and pumice, gravel and crushed stone
- Recycled aggregates: crushed brick, slag, crushed or foamed glass or crushed tiles
- Porous mats: of polystyrene, plastic or organic material
- Lightweight plastic drainage cells: high strength, interlocking modules with some designs creating a water store/reserve
- Subsoil drainage such as perforated PVC agricultural pipes (in intensive green roofs and raised garden beds) (City of Sydney, 2010).

Geofabric filter layer
The geofabric layer is installed on top of the drainage layer. It prevents the fine particles of the growing medium being washed into the drainage layer and causing blockages in the drainage. This filter layer can be either a woven or non-woven material. Non-woven material is preferable because it is more resistant to root penetration. They can sometimes be used as a root barrier system and are typically made of polyester fibres.

Growing medium
Green roofs require a special type of growing medium. Because it is on a roof, it should be a lightweight engineered soil. It is typically a mix of organic or inorganic material. Depending on the size of the project, the growing medium can be a standard pre-mixed mixture or a customised soil mixture that can be developed by a soil expert.

Carefully select and design the growing medium for the particular green roof type, for example:

- **an extensive roof requires a well-drained, open mix with more inorganic than organic material**
- **an intensive roof may be a mixture of organic and inorganic material such as an engineered, lightweight soil.**

Growing medium containing clay is not recommended as the fine particles can block the filter fabric and cause drainage issues.

The growing medium must have the following properties:

- Efficient moisture retention
- Well aerated
- Well drained
- Ability to absorb and supply nutrients
- Retain volume over time
- Provide anchorage for plants
- Lightweight
- Fire resistance

On steep sloping green roofs, erosion control methods such as interconnected cell products need to be installed to stabilise the growing medium. This will prevent erosion, especially while the plants are establishing.

Mulch should be placed on top of the growing medium to reduce weeds and water requirements. Inorganic mulch (such as decorative gravel aggregates), is more suitable than organic mulch. Aggregates have advantages over organic mulches such as pine bark, as they do not break down over time, and therefore will not need replacing at regular intervals.

Plants
Plant selection depends on a number of factors including site conditions and the design objectives.

Plants used on extensive green roofs are typically shallow and fibrous rooted, low-growing and hardy plants, such as ground covers, succulents and grasses. Plants that are adapted to high sun exposure, high temperatures and dryness are suitable, such as native grasses and succulents which have evolved to meet the harsh conditions of semi-arid Australia. Plants with similar soil, irrigation and drainage requirements should be selected and planted together in zones (Refer Section 6: Design and Planning).

Council recommends local native species are sourced locally from the Native Plant Nurseries in the LGA, as per the recommended plant schedules in the previous section.

Planting methods include seeding, hydro-seeding, spreading of sedum sprigs, planting of tubestock or container plants, and installing pre-cultivated vegetation mats (City of Sydney, 2014).

Intensive green roofs typically have a greater variety of plant species because they have deeper soils. Relatively large trees can be placed over the building's structural grid, such as columns, where the extra load can be carried safely.

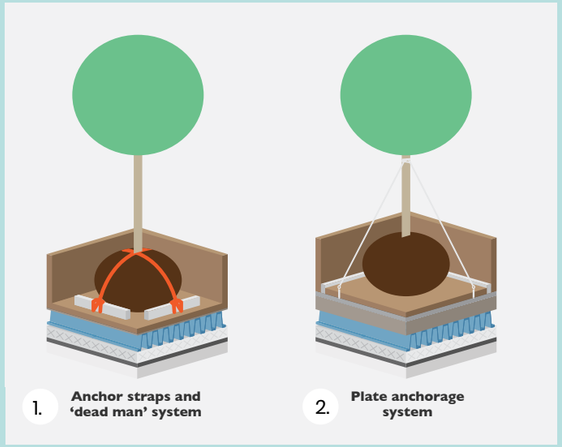
Trees on intensive green roofs will require anchoring to secure them against high wind conditions. There are 2 main options for anchoring trees on a rooftop.

They are:
- root ball anchor strap system
- plate anchor system

The rootball anchor strap system secures the tree under the surface of the soil. This means that there are no visible stakes or anchor straps (refer diagram on previous page). This system sometimes includes a woven mat which is placed over the top of the rootball to provide extra stability and fix the tree in place more securely. There are a range of different root ball anchor strap products on the market.

The plate anchor system includes a plate which sits under the root ball of the tree and straps which are fixed to the trunk. Refer page 29 for more information.

Example of a plate tree anchorage system.
(Source: ZinCo, 2019)



The two main types of tree anchoring systems
(Source: Growing Green Guide, 2015)

Irrigation
Installing an irrigation system is recommended, depending on the water requirements of the plant species. Grouping plant species with the same irrigation requirements is preferable. Irrigation typically is more frequent immediately after planting as the plants establish.

Installing a weather station to monitor conditions on the green roof can help tailor the irrigation approach and watering can be adjusted accordingly.

Irrigation methods for green roofs include:
- Hose irrigation: requiring connection to water points
- Automatic irrigation system: programmed to irrigate at set times
- Semi-automatic system: programmed system with manual overrides
- Drip-irrigation system: on the surface or under the surface

The type of irrigation selected helps determine the frequency, timing and duration of watering. Subsurface drip irrigation systems deliver water to the root zone and keeps it there. It typically delivers water more slowly over a longer period of time whereas spray irrigation delivers more water over less time onto the leaves and whole planted area.

Irrigation systems include 3 components:
1. drip or sprinkler-based distribution system
2. hydraulic module (includes valves, filters and pressure regulators)
3. control module (for programming and automation of system)

Where possible, a rainwater tank should be installed to water the green roof. Council encourages the use of greywater for irrigation.

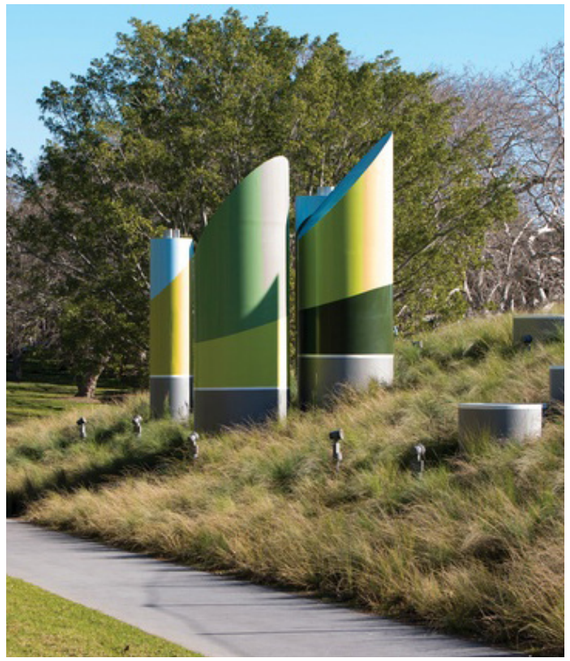
If the intent is to harvest water for irrigation for use on the roof, reticulation and storage of the harvested water will need to be included. Collected water should be gravity fed to the storage point where possible. Buildings that have a location for water storage at a lower level will require a pump.

Other elements of a green roof

A green roof may also have things like seating, pergolas, BBQ, pathways, solar panels, art elements, lighting and balustrading, depending on the design objective.

This will also vary depending on the type of green roof. An intensive green roof is typically designed to be more accessible for people to use it for passive recreation and would feature elements such as seating and pergolas.

Spray irrigation on a green roof
(Source: VEgetal i.D., 2019)



Sculptural art on a sloping green roof, Prince Alfred Pool, Surry Hills
(Source: Brett Boardman, 2017)

b. Green walls

The following section details the different types of green walls and their components. Green walls are made up of a series of elements fixed to a vertical structure. These vary depending on the type of green wall but typically include:

- waterproofing layer
- support structure
- growing panel (modular or felt panel)
- growing medium
- plants
- irrigation

Two broad types of green walls are:

1. Hydroponic systems - felt or vegetated mat
2. Modular panels - typically pre-planted with the plant growth established off site before installation

They can either be fixed:

- to a structural framework in front of a wall
- directly to a wall

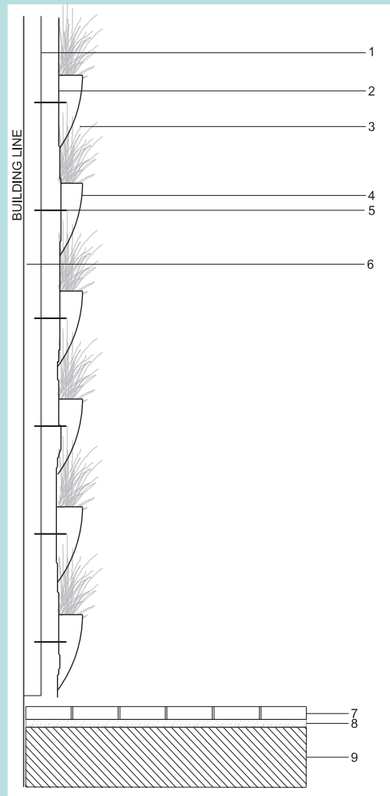
Hyrdoponic green wall systems are installed via brackets that sit out from the load-bearing wall (or a stand-alone structure) to create an air gap between the wall (or other structure) and the backing sheet of the green wall system.

Modular panels are made up of a series of containers which are connected together and anchored to the wall or to an independent, structurally secure metal rack or framework. Alternatively, plastic or metal growing containers can be hung on a metal grid fixed to the wall.

Green walls can be located on external or internal walls.

Typical construction

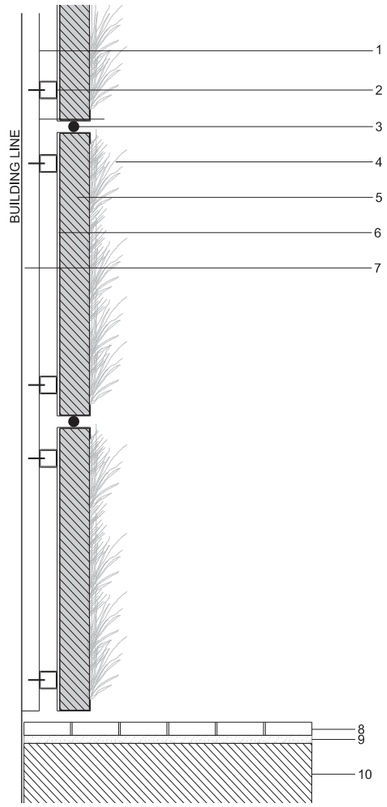
Green wall (felt mat hydroponic system)



1 STAINLESS STEEL WALL CHANNEL
2 FELT LAYER
3 PLANTS
4 POCKET
5 TIE
6 WATERPROOF MEMBRANE
7 PAVING
8 BEDDING COURSE
9 EXISTING PAVING SUBSTRATE

(Source: OEH, 2015)

Green wall (modular panel system)



1 STAINLESS STEEL WALL CHANNEL
2 STAINLESS STEEL PURLIN FIXED TO WALL CHANNEL
3 IRRIGATION LINE
4 PLANTS
5 GROWING MEDIUM
6 WALL PANEL
7 WATERPROOF MEMBRANE
8 PAVING
9 BEDDING COURSE
10 EXISTING PAVING SUBSTRATE

(Source: OEH, 2015)

Green wall panel, Top Ryde Shopping Centre, Ryde.

Waterproofing
The need for waterproofing varies depending on the green wall project.

When waterproofing is unnecessary
Where there is a sufficient air gap between the back of the planting system and the wall, waterproofing is unnecessary. The air gap prevents water moving between the wall and the planting system, and air-prunes plant roots to reduce the risk that they directly contact the wall and provide a path for the movement of moisture. Allowing an air gap between the planting system and the building wall also prevents mould from growing. In temperate and slightly humid climates such as Sydney, the gap required should be 50mm to 100mm to allow the natural convection air movement behind the wall which also removes the humidity (City of Sydney, 2014).

Some building materials are also sufficiently waterproofed in themselves, for example thick preformed concrete and marine-grade plywood. If the wall is constructed from these materials, extra waterproofing treatment is unnecessary (Tensile Design & Construct, 2019).

When waterproofing is necessary
Where an air gap is not achieved, waterproofing is required. Wall materials vary in their waterproofing qualities and the use of a liquid applied waterproofing layer is advisable as added protection if the air gap is not achieved and the wall material or owner concern warrants it. Roller-applied liquid waterproofing treatments are recommended and can be used for internal and external green walls.

When considering waterproofing for any green wall, seek advice from a waterproofing consultant to ensure the most suitable treatment is chosen. The manufacturing and installation of waterproofing membranes should comply with the Australian Standard for membranes used to waterproof exterior areas of buildings (AS 4654.2-2012 Waterproofing membranes for external above ground use – Design and installation).

Waterproofing for a green wall
(Source: Bravada, 2019)

Growing medium
The growing medium needs to be a special mix designed specifically for plants growing on green walls. Traditional potting mix is not a suitable growing medium for this type of project.

The type of green wall also influences the properties of the growing medium.

Hydroponic system
In a hydroponic system, an inert growing medium is provided for the plants to physically anchor to, such as a horticultural foam, a mineral fibre or a felt mat. These materials can act as a sponge so it is important to note that the more water they soak up the heavier the system becomes.

Modular panels system
In modular panels systems, the growing medium provides a structure to support the plant and facilitates water, air and nutrient access. This decreases the need for more frequent management associated with hydroponic systems. However, over time the reserve of nutrients will be exhausted and there can be a build up of salts in the growing medium. Fertiliser needs to be applied over time, and the growing medium may need to be replaced.

A specialist green wall provider will be able to advise on the most appropriate growing medium for each particular green wall design.

Irrigation
Appropriate levels of water and nutrients are essential for the success of green walls. The quality, design and costs will vary between different irrigation systems. The most sophisticated systems enable the maintenance supervisor to keep track of the automated performance of the system, including the volume of irrigation delivered, its frequency, substrate moisture content, as well as pH and nutrient levels in the water supply (Department of Environment and Primary Industries, 2014).

Irrigation and nutrient requirements vary between the different types of green walls, the location and orientation of the wall, and the plants growing in the wall.

Hydroponic system
In hydroponic systems, plant nutrition is delivered by a fertiliser injection system that releases controlled doses of fertiliser into the irrigation system (fertigation). Management of fertigation systems and rates of delivery requires specialist knowledge as it is more complex than fertilising soil or growing media.

Modular panels system
Modular panels systems are typically irrigated using drip lines. Some have irrigation lines integrated into the system. Water, nutrients and fertilisers can travel downwards through the modules. Excess water may be collected for reuse at the base in a drip tray and fed back into the system. This is particularly important if the green wall is located inside a building. Water must be collected at the base of the wall.

Green walls that use a high quality, water-retentive growing medium and are not in an exposed or particularly hot location, may thrive on a weekly watering regime. In most simple soil-based systems, including DIY systems, controlled release fertiliser is mixed in with the growing medium rather than using a fertigation system. Automated systems can be very useful, especially for larger walls. Sensors can also be used to monitor water and nutrient levels and provide automatic irrigation and/or fertiliser when necessary.

Where possible, irrigation should be connected to a sustainable source of water - from greywater or a rainwater tank. This will reduce the use of potable (drinking quality) water for watering the plants in the green wall.

Plants
The dimensions of the planting module or opening in the green wall determine the size of the planting stock. Generally, it is best to use tube stock. Using smaller plants at the start typically results in better long-term outcomes as the plants better adapt to the specific conditions of the site. However, the size of plant materials used in green walls will depend on the required look and finish of the wall at the time of completion. Plants in modular panels can be pre-grown off site prior to installation, providing instant greening when installed.

Planting densities can be as high as 25 to 30 plants per square metre, depending on the species to be used.

Council encourages the use of local native plants for green walls to protect and increase local biodiversity. These plants are suited to the local climate and conditions.

Consider lighting for green wall if it is located inside a building, or in a low light area. Lighting requirements are a major design consideration for internal green walls. Work with a lighting designer. If the LUX level is below 6000 LUX, artificial supplementary lighting will be required for an interior green wall (OEH, 2015).

Internal green wall, Bankstown Library and Knowledge Centre
(source: Junglefy, 2020)

c. Green facades

Green facades and their components are detailed in this section.

Green facades are made up of a series of elements fixed to a vertical structure. These typically include:
support structure for plants to grow on
- growing medium
- drainage
- plants
- irrigation

Green facades range from complex systems for multi-storey buildings with plants growing in planter boxes at different heights, to simpler systems where the plants grow up from the ground (Department of Environment and Primary Industries, 2014).

The two broad types of green facades are:
1. cable or wire net system
2. modular system

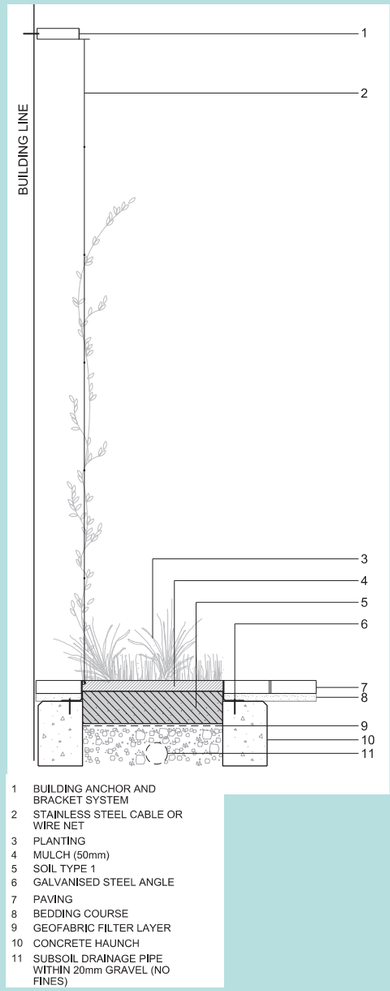
Green facades use climbing plants that grow up a climbing structure of some description. This structure can be single cables, a trellis system, a wire net or mesh system or a modular system. The structure is either fixed onto a wall or external facade or constructed as part of a frame or trellis type structure.

Consider the desired outcome for the green facade - the amount of coverage to be provided by the plants. If the green facade is being retrofitted onto an existing building, consider the architectural style of the structure. It is important to retain natural light entering the building, especially if the green facade is constructed on an apartment or office building.

Green facade using cable system with planter boxes, Nishi Building, Canberra

Typical construction

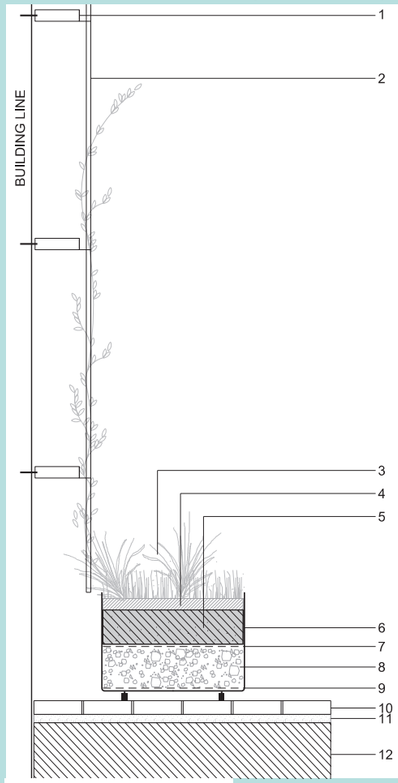
Green facade (cable or wire net system)



1 BUILDING ANCHOR AND BRACKET SYSTEM
2 STAINLESS STEEL CABLE OR WIRE NET
3 PLANTING
4 MULCH (50mm)
5 SOIL TYPE 1
6 GALVANISED STEEL ANGLE
7 PAVING
8 BEDDING COURSE
9 GEOFABRIC FILTER LAYER
10 CONCRETE HAUNCH
11 SUBSOIL DRAINAGE PIPE WITHIN 20mm GRAVEL (NO FINES)

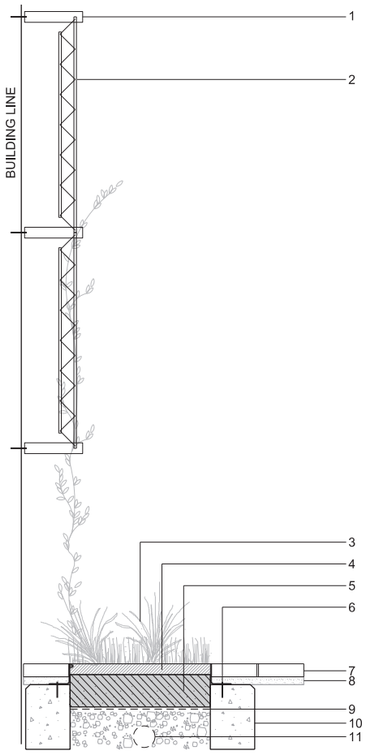
(Source: OEH, 2015)

Green facade (trellis and planter box system)



1 BUILDING ANCHOR AND BRACKET SYSTEM
2 TRELLIS SYSTEM FIXED TO BUILDING ANCHORS
3 PLANTING
4 MULCH (50mm)
5 SOIL TYPE 1
6 GALVANISED STEEL PLANTER
7 GEOFABRIC FILTER LAYER
8 20mm GRAVEL (NO FINES) LAYER
9 GEOFABRIC FILTER LAYER
10 PAVING
11 BEDDING COURSE
12 EXISTING PAVING SUBSTRATE

Green facade (modular trellis panel with in-ground planting)



1 BUILDING ANCHOR AND BRACKET SYSTEM
2 STAINLESS STEEL CABLE OR WIRE NET
3 PLANTING
4 MULCH (50mm)
5 SOIL TYPE 1
6 GALVANISED STEEL ANGLE
7 PAVING
8 BEDDING COURSE
9 GEOFABRIC FILTER LAYER
10 CONCRETE HAUNCH
11 SUBSOIL DRAINAGE PIPE WITHIN 20mm GRAVEL (NO FINES)

(Source: OEH, 2015)

Green facade, Rouse Hill Town Centre

Support structures

Support structures can be made of a range of materials including timber, metal, plastic or stainless steel. A green facade where the plants are grown on a support system that is installed separately reduces the risk of plants damaging the building or structure.

Design of the support structure must consider the intended lifespan of the facade, the growth habit of the selected plant species, and the spacing and offset from the wall. Different designs favour the growth of different plant species.

Metal systems have the longest lifespan and require less maintenance than other materials. Stainless steel mesh and cables are commonly used in green facades.

There are two main types of stainless steel support structures:

1. Steel cables and trellises:
   - offers the greatest flexibility to suit a variety of plant species and wind loads
2. Steel nets and mesh:
   - has closer 'weaves' with a cross-hatch than horizontal and vertical steel cabling
   - provides a supportive structure for plants to grow up and over
   - can provide a more uniform, consistent coverage of the climbers, more than wires

Stainless-steel support structures must be engineered and correctly tensioned for the weight of the plants and other elements. For cables this is 8kg per square metre, while for mesh it is 20kg per lineal metre (Tensile Design & Construct, 2019). The weight of any planter boxes must be factored in as well.

Wooden structures are prone to damage by weather and plant growth and require more regaular maintenance.

Plastics are discouraged as they can become brittle over time with ongoing exposure to UV light, heat and cold.

Top: Green facade using steel mesh, Vance Apartments, Harold Park
Bottom: Green facade using steel cables, 'Life House' Building, Camperdown
(source: Tensile Design & Construct, 2019)

Planter box design
Planter boxes should be designed to support plant growth. Consider the plants intended to grow in the boxes when sizing. Planter boxes can support a range of climbers and groundcovers and potentially small shrubs as well. Plant roots will typically grow to 200mm deep so the boxes do not need to be particularly deep.

It is best to avoid plant boxes which are dark colours as they get hot, especially in summer, resulting in unfavourable growing conditions for the plants. Plastic planter boxes should be avoided as they can split over time. Steel and concrete are durable materials to use and are recommended.

Planter boxes should be designed with an integrated irrigation system as they can dry out easily especially if located in a hot, windy position. Refer page 64 for more infromation on irrigation.

Waterproofing
Green facades rarely require waterproofing because they sit outside the building envelope. Where a green facade is constructed against a solid wall waterproofing is not required. The plants grow on a support structure rather than against a wall so there is no need for waterproofing.

However, it is important to select plant species that will not damage the fabric of the wall. Even if they are not designed to grow on the wall, some species with adventitious roots (roots that generally grow above the ground's surface) or scrambling stems can damage the building fabric over time, such as Common Ivy (*Hedera helix*).

Green facade, Nishi Building Canberra

Growing medium
The growing medium used for green facades varies depending on the type of green facade and whether the plants are grown in-ground or in planter boxes.

Engineered, lightweight soil should be used for planter boxes. The growing medium used for green facade planter boxes is the same type of growing medium as for green roofs. The roots of plants growing on green facades typically grow in soil a minimum of 150-250mm deep (Hopkins et al 2010). The growing medium must be kept moist and be free draining to avoid drying out or becoming waterlogged.

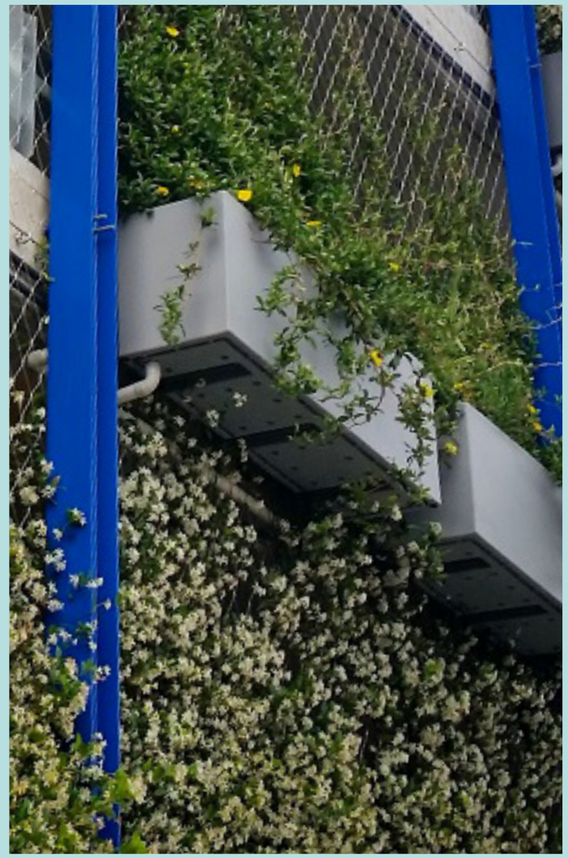
If the plants are grown in the ground, a typical garden mix can be used for the garden bed planting. Drainage should be provided to ensure the garden bed does not get water-logged.

Mulch should be placed on top of the growing medium in on grade planter beds and planter boxes, to reduce evaporation, the chance of and reduce irrigation requirements

Drainage
Planter boxes should be filled with a free-draining growing medium to avoid potential waterlogging. Providing drainage holes in the sides of the container, just higher than the level to which the container is filled with soil will minimise the risk of ponding of water in the planter box.

Subsoil drainage should be included in in-ground systems. This is especially important when the planter bed is against a building and surrounded by pavement.

A subsoil drainage pipe (similar to an ag line or slotted PVC pipe) embedded within a gravel layer will prevent water-logging.


Green facade, Super Yacht Car Park Rozelle (source: Junglefy, 2017)

Plant selection

Green facades typically use plants which climb by twining (Transport for London, 2012). It is important to select plants with those properties. Refer Suggested Species List in Section 6. Depending on the height of the wall and the species selection, it could take 3-5 years before total vegetation coverage is achieved. If rapid coverage of a green facade is required, plant specimens should be healthy and vigorous. They should also be of the largest possible size to suit the installation.

Adhesive-sucker and root climbing plants (such as Ivy) should be avoided, as they can damage building walls (Tensile Design and Construct, 2018).

For systems using planter boxes, species choice and the spacing, and soil volume of the boxes are critical for establishing effective facade coverage.

Plants may need to be trained to grow on the facade support or temporarily attached to the support after planting to encourage the desired outcome. Depending on the plants chosen, regular pruning will help keep the green facade looking full and generate new growth.

Scrambling groundcover plants that do not grow too tall heights may also help to avoid a 'bare' look at the base of the green facade.

Irrigation

Irrigation is especially important for green facades which use planter box systems as they can dry out more easily than in-ground systems. Drip irrigation or sub-soil drip systems are recommended for planter boxes.

Depending on the scale of the project, at-ground plantings can be irrigated by automatic systems or manually with a hose.

The vigour of many climbing plant species means that irrigation will be required to maintain healthy growth. The frequency of irrigation depends on:

- the plant species selected
- the type of growing medium used
- how exposed the facade is to sun and wind

Water sensors can also be used in the planter boxes on green facades to monitor water levels and provide automatic irrigation as necessary.

Green roof, 88 Angel Street, Newtown

8. Maintenance

Maintenance planning
As with all projects, a maintenance plan and budget must be decided as part of the design process. Maintenance requirements are dependent on the type of green roof, wall or facade and the maintenance objectives. For example, intensive green roofs require more maintenance than extensive green roofs.

Maintenance is critical to the success of a green roof, wall or facade. Maintenance planning depends on:
- vegetation species and vigour
- use of the roof, wall or facade (e.g. if growing food versus creating a biodiversity space)
- preferences about the look of the roof, wall or facade
- number of likely weed seed sources around the site
- type of irrigation and its maintenance requirements (Department of Environment and Primary Industries, 2015)

A maintenance plan should include a clear description of:
- maintenance objectives – based on the design objectives for the roof, wall or facade development, and the expectation of the owner and/or building manager
- performance targets, such as the time frame for complete coverage of an area by plants and foliage
- responsibilities of various personnel involved in operating the building or managing the structure, outlining the type, scope, duration of task and occurrence
- frequency of maintenance tasks
- training requirements (such as Working at Heights certification) and safety equipment
- risk management, including WH&S requirements

Often maintenance will be undertaken by someone other than the owner of the building or structure. A maintenance agreement with the installation company or with a recommended third party may be the most economical way to ensure the best long-term performance of a green roof, wall or facade. If a maintenance contract is used, it is important to be clear about the duration, the scope of responsibilities, and the need for handover to new contractors or back to the building owner if and when that may take place. Formal access arrangements for staff, equipment and materials are required for maintenance activities.

Types of maintenance
The four different types of maintenance are:
1. Establishment maintenance
2 Routine maintenance
3. Cyclic maintenance
4. Reactive and preventative maintenance

1. Establishment maintenance occurs during the first one to two years after installation. The length depends on the project size, budget and client direction. For vegetation, this includes tasks such as plant replacement, pruning, weeding and irrigation.

2. Routine maintenance includes regular works to ensure the roof, wall or facade is maintained to a minimum or required standard of appearance, functionality and safety. It includes checking that the drainage system is clear of debris, usually at least twice a year.

3. Cyclic maintenance is scheduled at less frequent intervals to maintain the infrastructure. It includes maintenance of the underlying building structure and of specific components of the green roof, wall or facade system. This may include more major pruning of vegetation or annual treatment of hard landscape elements like decking.

4. Reactive and preventative maintenance is undertaken when a component of the system fails suddenly, or shows signs of imminent failure. Failure may be due to a long-term problem that has gone undetected (such as blocked drains by tree roots) or sudden damage resulting from an extreme weather event.

Maintenance access may require additional equipment, such as forklifts, elevated platforms or an industrial abseiling system.

Plant health
To ensure the success of the green roof, wall or facade, plants need to receive appropriate levels of fertiliser, depending on the requirements of each species.

For green walls, installers typically provide specific instructions for the nutrition requirements of the particular plants used in the wall.

For green roofs and facades, controlled release fertilisers (CRF) are the most suitable form of plant nutrition. Establish the lowest appropriate application rate for CRFs to prevent extra fertiliser washing out of the growing media and into the stormwater drainage system.

Insurance and warranties
While smaller projects may not include a warranty or insurance, it is an important consideration on larger projects. Manufacturers, suppliers and installers usually offer some kind of warranty or guarantee for the green roof, wall or facade. Different green roof, wall and facade products can come with different warranties so check with the provider. These include ‘component only’ warranties and ‘vegetation coverage’ warranties. The length of the warranty period can also differ dramatically between different companies and the types of installation. The vegetation itself is often not covered by the installer’s/manufacturer’s warranty, as the lifespan of this is largely dependent on the site’s specific characteristics and the plant species (The Renewable Energy Hub, n.d.).

Defects Liability Period
Similar to a maintenance period, a defects liability period is like a warranty period. It covers products used to construct green walls, roofs and facades. During this period, failure of the components of the structure are under warranty and it is the responsibility of the manufacturer or installer to repair the product.

9. Ratings tools, standards and further information

Green Building Ratings Tools

- Living Building Challenge
  https://living-future.org/lbc/
- Green Star
  https://new.gbca.org.au/
- National Australian Built Environment Rating System- NABERS
  https://nabers.gov.au
- NatHERS (Nationwide House Energy Rating Scheme)
  http://www.nathers.gov.au/

Building Regulations and Standards

- National Construction Code (NCC) Volume 1 Section J: Energy Efficiency Provision Changes and Volume 2 Part 3.12 Energy Efficiency Provision Changes
- Various Australian Standards for building and structural design, waterproofing, insulation, drainage, geotextile/filter layer, growing medium, plant stock and fire safety including:
  - AS/NZS 1170.0:2002: Structural Design Actions – General Principles
  - AS ISO 13822-2005: Basis for design of structures – Assessment of existing structures
  - AS/NZS 1170.2:2011/Amdt 1-2012: Structural Design Actions – wind action
  - AS 4654.2-2012: Waterproofing membranes for external above-ground use - Design and installation
  - AS/NZS 3500.3:2003: Plumbing and drainage – Stormwater drainage
  - AS 3706.1-2012: Geotextiles – Methods of test- General requirements, sampling, conditioning, basic physical properties and statistical analysis
  - AS/NZS 4859.1:2002: Materials for the thermal insulation of buildings – General criteria and technical provisions
  - AS 4419-2003: Soils for landscaping and garden use
  - AS 1530.2: Methods for fire test on building materials, components and structures – test for flammability of materials
  - AS 1428: Design for Access and Mobility
- Work Health and Safety Act 2011
- BASIX (Building Sustainability Index) NSW Department of Planning and Infrastructure

Further Information and Resources

Design Guides

- 'Your Home Technical Manual' (Department of Environment and Energy, 2013)
  http://www.yourhome.gov.au/materials/green-roofs-and-walls
- Green Roofs and Walls Design Guide, Resource Manual and Waterproofing Guide (City of Sydney, various publication dates)
  http://www.cityofsydney.nsw.gov.au/vision/sustainable-sydney-2030/sustainability/greening-the-city/green-roofs-and-walls
- Green Roof and Wall Resource Manual (North Sydney Council, n.d.)
  https://www.northsydney.nsw.gov.au/Building_Development/Other_Planning_Documents/Green_Roof_Manual
- Adelaide Design Manual Greening Guidelines and Design Standards and Green Infrastructure Guidelines (City of Adelaide, 2014)
  http://www.adelaidedesignmanual.com.au/design-toolkit/greening
- New World City Design Guide: Buildings that Breathe (Brisbane City Council, 2016)
  https://www.brisbane.qld.gov.au/planning-and-building/planning-guidelines-and-tools/neighbourhood-planning-and-urban-renewal/new-world-city-design-guide-buildings-that-breathe
- Ecoroof Handbook (City of Portland Environmental Services Department, 2009)
  https://www.portlandoregon.gov/bes/44422
- Design Guidelines for Biodiverse Green Roofs (City of Toronto, 2013)
  https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/green-roofs/biodiverse-green-roofs/
- Handbook on Developing Sustainable Highrise Gardens: Bringing Greenery Skywards (National Parks Board, 2017)
  https://www.nparks.gov.sg/-/media/srg/files/handbook-1.pdf

Technical Guidelines

- Urban Green Cover in New South Wales Technical Guidelines (Office of Environment and Heritage, 2015)
  http://climatechange.environment.nsw.gov.au//Adapting-to-climate-change/Green-Cover
- Growing Green Guide: A guide to green roofs, walls and facades in Melbourne and Victoria (University of Melbourne and Cities of Melbourne, Yarra, Stonnington and Port Phillip, 2014)
  http://www.growinggreenguide.org/
- Living wall and green roof plants for Australia (Rural Industries Research and Development Corporation, 2012)
  https://www.ngina.com.au/Story?Action=View&Story_id=1110
- Green roofs and walls RICS Guidance note, Australia (Royal Institution of Chartered Surveyors, 2016)
  https://www.rics.org/oceania/upholding-professional-standards/sector-standards/construction/green-roofs-and-walls/
- Rain Gardens, Green Roofs and Infiltration Systems, Water Sensitive Urban Design Technical Manual Greater Adelaide Region
  https://www.sa.gov.au/__data/assets/pdf_file/0011/11540/WSUD_chapter_6.pdf
- NATSPEC 'Specifying Trees – a Guide to Assessment of Tree Quality' (Clark, R 2003)

Useful Websites

- Green Roofs Australasia
  https://greenroofsaustralasia.com.au/
- Living Roofs
  https://livingroofs.org/
- City of Sydney Green Roofs and Walls
  http://www.cityofsydney.nsw.gov.au/vision/towards-2030/sustainability/greening-the-city/green-roofs-and-walls
- City of London Green Roofs
  https://www.cityoflondon.gov.uk/services/environment-and-planning/planning/design/sustainable-design/Pages/green-roofs.aspx

- Greening London
  https://www.london.gov.uk/what-we-do/environment/parks-green-spaces-and-biodiversity/greening-london
- National Parks Singapore Skyrise Greenery
  https://www.nparks.gov.sg/skyrisegreenery
- Safe Design, Safe Work Australia
  https://www.safeworkaustralia.gov.au/safe-design

NOTE: Overseas resources are provided for information only. Different plant species and construction requirements may be required for Sydney.

Green wall (breathing wall), Mitchell Street Plaza, St Leonards
(Source: Junglefy, 2018b)

10. Glossary

Australian Standard (AS)
Standards set out specifications, procedures and guidelines that aim to ensure products, services, and systems are safe, consistent, and reliable. Australian Standards are developed either by a national standards body (like Standards Australia) or other accredited bodies. (Standards Australia, 2018)

Biodiversity Sensitive Urban Design (BSUD)
Biodiversity sensitive urban design is a protocol for urban design that aims to create suburbs that are a net benefit to native species and ecosystems through the provision of essential habitat and food resources. (Garrard, 2012)

Building Code of Australia (BCA)
The Building Code of Australia contains technical provisions for the design and construction of buildings and other structures. The BCA is produced and maintained by the Australian Building Codes Board on behalf of the Australian government and state and territory governments. (South Australian Government, 2018)

Building Maintenance Unit (BMU)
A building maintenance unit is an automatic, remote-controlled, or mechanical device, usually suspended from the roof, which moves systematically over the vertical surface of a structure while carrying human window washers or mechanical robots to maintain or clean the surface.

Development Application (DA)
A DA is a formal application for development that requires consent under the NSW Environmental Planning and Assessment Act 1979 (EP&A Act). It is usually made to your local council and consists of standard application forms, supporting technical reports and plans.
(Department of Planning, 2018)

Development Consent
Development consent is given when a DA is is approved by Council.

Development Control Plan (DCP)
A document prepared by local council for the local government area (LGA) to guide development according to the aims of the corresponding Local Environmental Plan (LEP).

Dead load
The entire green roof assembly, including plants and the water required to saturate the growth media, is considered the dead load of the structure. (Green Roofs, 2010). See also live load.

Ecosystem services
Ecosystem services are the benefits that plants, animals, water, soil, and air provide, e.g:

- trees acting as carbon sinks and providing oxygen and cooling;
- landscapes providing habitat, food, aesthetic, cultural and mental health benefits;
- fungi and insects supporting the food chain, soil formation and breaking down waste;
- bees, bats and birds pollinating plants.

(Inner West Council, 2017)

Extensive green roof
An extensive green roof has a growing medium depth of approximately 150mm. (OEH, 2015)

Fertigation
A fertiliser injection system that releases controlled doses of fertiliser into the irrigation system on a green wall.

Growing medium
The material in which plants grow.

Green wall
Green walls are vegetated systems that are grown on the vertical facade of a building envelope or other structure. They incorporate multiple 'containerised' plantings to create vertical greening.

Green facade
A green facade is a system where plants are trained to grow on specifically-designed supporting structures, such as a trellis system of either cables or mesh to support the climbing plant off the building surface. (OEH, 2015)

Intensive green roof
An intensive green roof has a growing medium of more than 150mm deep, requires a stronger roof structure and is capable of sustaining larger plant species such as shrubs to trees. (OEH, 2015)

Local Environment Plan (LEP)
A Local Environmental Plan (LEP) is a legal document that provides controls and guidelines for development in an LGA. It determines what can be built, where it can be built, and what activities can occur on land. LEPs contain both a written instrument and maps. These should be viewed together to provide an understanding of zoning and building controls across the area or for a particular property. (Inner West Council, 2019)

Live load
Live load refers to the weight of a green roof, factoring variables which change over time. This typically includes water in excess of that which saturates the growth media and people visiting the green roof. (Green Roofs, 2010) See also dead load.

Living wall
Living wall is another name for green wall.

Microclimate
The localised climate affecting a particular site.

National Construction Code
The NCC provides the minimum necessary requirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia. The NCC was developed to incorporate all on-site construction requirements into a single code. It covers the Building Code of Australia and Plumbing Code of Australia and is managed by the ABCB. (Business.gov.au, 2018)

Potable water
Water that is safe for humans to drink.

Substrate
Substrate is another name for growing medium.

Urban Heat Island (UHI)
The Urban Heat Island effect is localised warming due to the increase in the large amounts of paved and dark coloured surfaces like roads, roofs and car parks as a result of urban development. (OEH, 2015)

Water sensitive urban design (WSUD)
WSUD is an urban planning, engineering and landscape design approach which integrates urban water cycle management (water supply, stormwater, groundwater, wastewater), with urban design to provide multiple benefits including improving environmental health and supplying ecosystem services. (Inner West Council, 2017)

Green wall and facade, One Central Park, Chippendale (Source: Simon Wood, 2018)

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