

Green Roofs and Walls

From the turf roofs of Viking dwellings in Scandinavia to the 'hanging' gardens of ancient Babylon, green roofs have a history reaching back thousands of years. Modern green roofs and walls are building elements designed to support living vegetation in order to improve a building's performance. Also known as 'living' roofs and walls, they are emerging as important additions to the palette of construction techniques for creating healthy, ecologically responsible buildings.



A green roof is a roof surface, flat or pitched, that is planted partially or completely with vegetation and a growing medium over a waterproof membrane. They may be 'extensive' and have a thin growing medium (up to 200mm deep) with 'ground cover' vegetation, or 'intensive' and have a soil 200mm deep or more supporting vegetation up to the size of trees. Green walls are external or internal vertical building elements that support a cover of vegetation which is rooted either in stacked pots or growing mats.

Green roofs are an accepted part of modern building in Europe where some city and even national governments have mandated their use (Linz, in Austria requires green roofs on all new residential and commercial buildings with rooftops larger than 100m², German green roof building has been encouraged by the Federal Nature Protection Act, the Building Code and state-level nature protection statutes). Australian examples are less common but in 2007 a national organisation was formed to promote green roofs and Brisbane City Council included green roofs in its proposed action plan for dealing with climate change.

Earth-sheltered houses have green roofs and anyone who has grown climbers across a vertical trellis has had some experience in creating green walls. The growing interest in green roof and wall construction has been encouraged by the increasing availability of technologies that make their construction easier and more economical.

Green roofs are particularly effective in denser, more urban environments, where they can compensate for the loss of productive landscape at ground level. 'Green wall' techniques can be used on homes in suburban settings as part of aesthetic enhancement and improving the overall climate responsiveness of individual dwellings, and even to treat wastewater.

PERFORMANCE SUMMARY

The benefits of green roofs include:

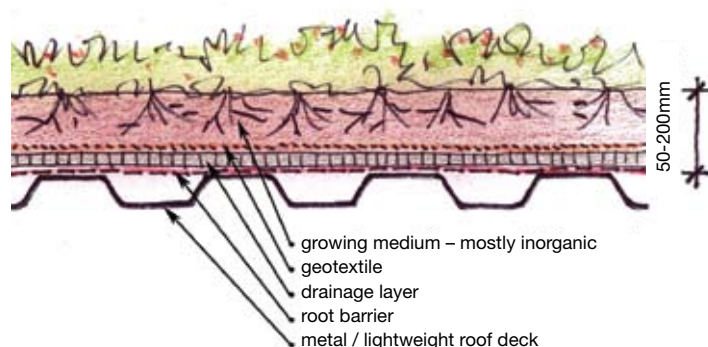
- > Longer roof lifespan.
- > Improved sound insulation.
- > Reduced heating and cooling requirements.
- > Reduced stormwater run-off.
- > Trapping of gaseous and particulate pollutants.
- > Alleviation of urban heat islands.
- > Increased biodiversity.

Many of these benefits also apply to green walls.

Green roofs are sometimes referred to as the fifth façade. There are two kinds of green roof: intensive and extensive, each of which is appropriate for different purposes. The intensive roof is typically much heavier, supports more substantial vegetation and is more expensive than 'extensive' roofs that are often light enough that they can be retrofitted to existing buildings without the need to upgrade their structural capabilities.

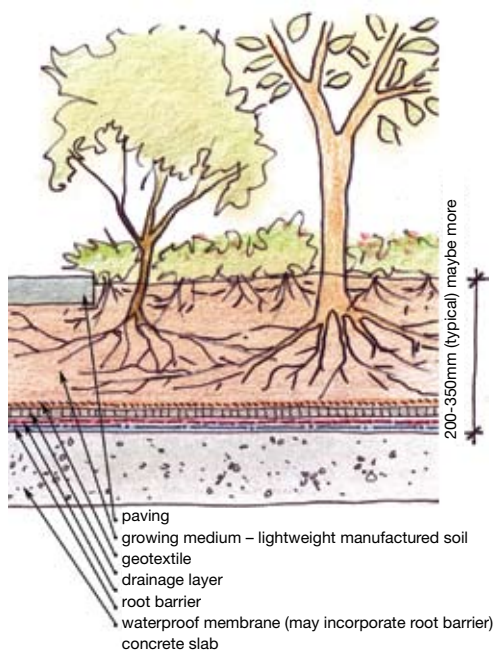
Extensive green roofs

- > Shallow growing medium – 50 to 200mm.
- > Roof structure similar to conventional roof coverings.
- > Vegetation limited to shallow rooting plants.
- > Relatively economical.
- > Relatively easy to retrofit.



Intensive green roofs

- > Deep growing medium – 200mm or greater.
- > Requires stronger roof structure.
- > Wide range of plantings possible.
- > Relatively expensive.
- > Difficult to retrofit.



In between these types there are semi-extensive (extensive with areas of deeper soil) and semi-intensive roofs (intensive with areas of shallower soil).

GREEN WALLS

Green walls are like vertical gardens and may be inside or outside of a building. In their more elaborate form, green walls are 'living walls' and may incorporate water elements including ponds and fish. Green walls may also be incorporated into the cooling strategy of a house, as a kind of evaporative air conditioner, and they may even be designed as part of a water treatment system. Green walls include:

- > Green facades – pots with vines on trellises.
- > Active – with soil/growing medium running up wall.
- > Passive – epiphytes.



Appearance

Green roofs can look like anything from a lawn to a forest. Extensive green roofs that use a thin layer of growing medium to support ground cover plants with short roots are generally designed with building performance in mind rather than aesthetic concerns. Sloping and curved extensive green roofs may be seen from ground level.

Intensive roofs can support quite substantial, highly visible vegetation, cascading over the sides of the building or as shrubs and trees rising above the roofline. These are commonly referred to as roof gardens. By creating a landscaped surface green roofs can radically change a building's 'roof line'.

Green roofs and external green walls (which can be small and incidental or large and dramatic) extend the scope for creating pleasant urban environments by introducing plants and greenery that are visually restful or refreshing. Proven therapeutic effects include increased productivity and reduced absenteeism.



Indoor greening can be either an extension of the green wall concept or can include the creation of indoor planters as integral parts of the house. Green walls make it possible to have lots of greenery without using too much floor space. Imagine walking into a room with plants covering one or more of the wall surfaces – living greenery on vertical surfaces can create quite striking impacts.

Green wall systems range from arrangements of planting pots on layers of custom shelving to sophisticated vertical layers of growing medium, geotextiles and purpose made containers. Depending on the size of the wall, large or small plants can be used and the result can be manicured and elegant (think of a privet hedge) or wild and funky.

Green walls can humidify and oxygenate the air and, depending on the plant species, can further improve indoor air quality by acting as

filters, trapping dust and absorbing pollutants like formaldehyde.

Structural capability

Green roofs are usually flat but may also be curved or sloping. Supporting structures have to carry all the loads associated with the vegetation, its supporting medium, and the waterproofing and protective layers beneath – plus any live loads from people using the roof.

Extensive green roofs, in particular, can create desiccated, harsh environments for vegetation. Often situated in urban areas, such roofs require low maintenance vegetation tolerant of heat, cold, drought and wind. Although there is limited experience in Australia of such roofs, it is likely that many native plants from coastal and arid inland regions are suited to use in such demanding environments.

Green walls may be freestanding structures or dependent on the building's main structures for support using trellises, cables or frames.

Thermal mass

There is little thermal mass in the vegetative component of green roofs and although there may be some mass in the soil, the usual growing medium is lightweight and is consequently more useful as insulation rather than thermal mass. Green walls have a relatively low thermal mass for the same reason. The supporting structure for extensive roofs (and green walls) is also usually lightweight, with little thermal mass, whereas the structures required for intensive roofs almost invariably employ concrete slabs or similar structures with an inherently high thermal mass.

Insulation

Green roofs may or may not include an insulating layer in addition to the soil and vegetation, but even without such a layer they provide significant thermal insulation. Overall insulation values depend on the type and thickness of growing medium and the type and extent of vegetation. There is little available documentation for R-values which will, in any case, vary according to the degree of saturation of the growing medium.

Green walls can be retrofitted to existing homes to reduce the heat load on façades. The simplest kind is a trellis set with a gap between it and its supporting wall to create shade from vegetation with passive cooling from transpiration of the vegetation and convection of heat up through the gap.

In warmer weather, green walls act like green roofs by reducing the surface temperature of a conventional wall through evapotranspiration and shading. Walls that use irrigation and hydroponic techniques provide additional cooling through evaporation.

Shading windows by deciduous vegetation (bioshading) reduces cooling demands by limiting solar gain in the summer whilst allowing daylight in during winter. The insulating and low thermal absorption properties of green roofs also reduces the urban heat island effect.

Sound insulation

In busy urban settings the acoustically absorbent nature of soil and vegetation of green roofs can insulate against the noise of heavy vehicles like trains, trams, buses and trucks. One office building under the flight path of San Francisco's International Airport, planted with a mixture of indigenous grasses and wildflowers, has been designed to achieve noise transmission reductions of up to 50 decibels.

An extensive thin green roof just 100mm deep will reduce noise transmission by at least five decibels.

Durability and moisture resistance

Green roofs can extend the life of their supporting structure and substrates. By preventing direct solar impact on water-proofing membranes, for instance, 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. Similar benefits derive from using green walls that add an extra 'skin' of protection to a building.

Green roofs should be designed to last at least 50 years. Replacement of any components of green roofs are relatively costly so key structural considerations include:

- > Longevity of the structure.
- > Appropriate drainage.
- > Waterproofing.



Fire and vermin resistance

The soil of any green roof is fundamentally fire resistant. The different kinds of vegetation that might be found on a green roof range from shallow-rooted succulents that burn very poorly and offer good fire resistance, to more substantial plants on intensive roofs that can include shrubs and even trees. Although very dry vegetation can present a hazard, the amount of dry vegetation on an extensive roof is unlikely to support more than low intensity fires.

The capacity of any roof-top vegetation to support on-going conflagration is limited and a green roof can be expected to have very good fire resistance, particularly if it is vegetated with succulents or when the growing medium is saturated. There are no relevant Australian codes as yet, but as an example, German building codes provide for 600mm fire breaks every 40m. Fire activated sprinkler irrigation can further reduce risk.

Vermin are offensive animals, insects and worms that are not wanted in human environments. They have not been identified as a problem for green roofs, perhaps because a green roof represents a deliberate effort to incorporate living material into a building and create habitat in which there is less imbalance between humans and other fauna.

Breathability and toxicity

Vegetation in urban areas can filter out fine airborne particles which then wash off into the soil and foliage can absorb gaseous pollutants so it can be reasonably assumed that green roofs provide the same services. Studies have shown that green roofs can trap up to 95 per cent of heavy metals in the local atmosphere.

Sustainability (environmental impacts)

Green roofs and walls contribute towards a wide range of sustainable development objectives, including:

- > Stormwater management.
- > Climate change mitigation and adaptation.
- > Conservation and enhancement of biodiversity.

Retention and binding of contaminants (bird droppings or atmospheric pollution) can assist removal of harmful pollution from run-off into aquatic ecosystems.

The potential for food production on green roofs is being actively investigated in Australia. Led by Central Queensland University (CQU), research includes using urban organic wastes via vermiculture for production of vegetables and development of urban rooftop 'microfarms'.

The heat island effect is reduced by green roofs. Researchers at the Welsh School of Architecture recently concluded that green roofs and walls can cool the local climate around a building in a city by between 3.6°C and 11.3°C and the hotter the climate, the greater the cooling effect.

By lowering ambient roof temperatures, green roofs enable solar panels mounted over them to operate more efficiently, with energy outputs up to 15 per cent more than from panels on asphalt or gravel covered roofs.

Electromagnetic radiation can be reduced by more than 99 per cent with a 100mm substrate depth.

Habitat can be created to increase biodiversity and attract wildlife including rare or migratory birds. Encouraging birds, butterflies and bees has been a significant aspect of some overseas suburban green roofs, whilst a large US manufacturer has a bee farm on the four hectare green roof above its new truck factory.

Green roofs can reduce the costs of dealing with the predicted nationwide increase in peak rainfall events associated with climate change in Australia by providing storm-water retention and slowing the run-off of rainfall. Student research at the University of Queensland has shown that run-off reductions of up to 42 per cent is achievable with only 100mm of soil planted with moderate growth turf, and that as the soil depth and vegetation water use is increased, so does retention capacity.

Domestic greywater treatment has been achieved in Australia using a green wall consisting of a series of three planter troughs which act as filters, removing nutrients, polluting compounds and organic matter from the water.

[See: 7.4 Wastewater re-use]

Buildability, availability and cost

Construction techniques are well understood and documented internationally with an increasing number of proprietary green roof systems available and Australian experience is developing rapidly. Green roofs present higher construction costs than conventional roofs with limited short term return on investment. Long term returns are potentially very good. Without legislation to encourage green roof construction, Australian uptake of the

technologies will be driven by building rating systems that value green roofs and recognition of improved market values.

Individual properties benefit from reduced maintenance and running costs and in North America and the UK green roofs are synonymous with quality, which is reflected in increased property values.

TYPICAL CONSTRUCTION

On top of the structural components, there are typically seven layers to a green roof:

1. Waterproofing membrane (either built-up roof, single-ply membrane or fluid-applied membrane. Modified bitumen or plastic sheeting most typical).
2. Root barrier (polyethylene sheeting, copper or copper compounds in the membrane).
3. Insulation (optional).
4. Drainage layer (synthetic drainage mesh, granular aggregate).
5. Filter fabric (geotextile).
6. Growing medium – also known as planting medium or substrate (manufactured soil, crushed brick or other inorganic material).
7. Vegetation (shallow-rooted on extensive roofs, deeper-rooted on intensive roofs).

Green walls are constructed with plants rooted in sheets of fibrous material which may be fixed to a wall or frame, or they may be constructed more like vertical arrays of pots or planters. Some proprietary green wall systems come in the form of modular panels. Plants may be pre-grown in these panels or planted after the panels have been installed.

Materials include steel for supporting frameworks, HDPE plastic for plant containers, and geotextiles. In exterior applications, irrigation may be from the top via soaker hoses or similar. Interior applications may use drip trays.

Both green roofs and green walls need to allow for irrigation of vegetation without loss of soil and to provide reservoirs of water to carry plants through periods of low water availability.



Things to watch out for

When installing a green roof it is important to consider:

- > The climate zone. [See: 4.2 Design for Climate]
- > Micro climate and roof orientation.
- > Local habitats and species.

Design issues

- > Structure.
- > Membranes.
- > Mats.
- > Drainage.
- > Trellises.
- > Plant selection.
- > Integration with building functions generally.

The correct growing medium for the climate and plant selection is essential, particularly for extensive roofs. Plant selection for green roofs requires careful consideration as different conditions apply to vegetation on the roof compared with ground level and long term plant maintenance is essential.

Maintenance demands are reduced by integrated irrigation, but a small green wall needs no more tending than more conventional indoor plant arrangements. Larger installations may include programmable and automated watering systems.

ADDITIONAL READING

There has been limited reference material published in English, and, as yet, no substantial publications that deal specifically with Australian conditions.

Dunnett N and Kingsbury N (2004), *Planting Green Roofs and Living Walls*, Timber Press, US.

Earth Pledge (2005), *Green Roofs: Ecological Design and Construction*, Schiffer Publishing, US.

Green Roofs Australia
www.greenroofs.org.au

Snodgrass E and Snodgrass L (2006), *Green Roof Plants*, Timber Press, US.

Werthmann C (2007), *Green Roof: A Case Study*, Princeton Architectural Press, US.

Principal author:

Paul Downton