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 can be an oasis in the city landscape.

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 ‘groundcover’ vegetation, or ‘intensive’ and have soil over 200mm deep supporting vegetation up to the size of trees.

Green walls are external or internal vertical building elements that support a cover of vegetation rooted either in stacked pots or growing mats.

Green roofs are an accepted part of modern building in Europe where some city and national governments have mandated their use. The Austrian city of Linz, for example, requires green roofs on all new residential and commercial buildings with rooftops larger than 100m², and 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.

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.

Earth-sheltered houses have green roofs by design, 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 and walls have become common features in illustrations of modern architectural and urban design proposals but their implementation remains limited by perceptions of high costs and questions over their utility. A changing climate and increasing demands for high levels of environmental performance are likely to see these arguments continue to shift in their favour.

Lettuce and herbs growing on an experimental green wall in Adelaide.
Green roofs can be particularly effective in denser, more urban environments, where they can compensate for the loss of productive landscape at ground level. Examples range from herbs growing on a 2m\(^2\) bicycle shed roof in Sheffield, England, to vegetables growing on a 558m\(^2\) organic rooftop farm in Brooklyn, New York. ‘Green wall’ techniques can be used on homes in suburban settings as part of aesthetic enhancement, to improve the overall climate responsiveness of individual dwellings, and even to treat wastewater.

The benefits of green roofs include:

- longer roof lifespan
- improved sound insulation
- reduced heating and cooling requirements
- reduced and slowed stormwater runoff
- capture of gaseous and particulate pollutants
- alleviation of urban heat island effects
- increased biodiversity.

There is also the potential for green roofs to provide carbon sequestration.

Many of these benefits also apply to green walls.

Green roofs are sometimes referred to as the ‘fifth façade’. Each of the two kinds of green roof — intensive and extensive — is appropriate for different purposes.

The intensive roof is typically much heavier, supports more substantial vegetation and is more expensive than ‘extensive’ roofs, which are often light enough to be retrofitted to existing buildings without the need to upgrade their structural capabilities.

There are no rigid categories for green roofs; the following descriptions are based on common use.

### Extensive green roofs

Extensive green roofs have a shallow profile. They provide much of the environmental performance benefits of deeper, intensive green roofs but cannot support general foot traffic. Their shallower profile means less substrate volume to store water and support root growth (although there is still enough to reduce and slow stormwater runoff), and this limits the variety of plant options to those that tolerate environmental stress, especially drought and desiccating winds.

![Extensive green roof](https://via.placeholder.com/150)

Cross-section of typical extensive green roof.

**Extensive green roof characteristics**

- Shallow growing medium — typically less than 200mm
- Roof structure similar to conventional roof coverings
- Weight 60–200kg/m\(^2\)
- Vegetation generally limited to low, shallow-rooting and groundcover plants that are tolerant of drought, wind exposure and temperature fluctuations
- Not suitable for general access
- Relatively economical
- Some thermal and acoustic insulation benefits
- Relatively easy to retrofit on existing roofs
- Low maintenance

Extensive green roofs, often situated in urban areas, 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 harsh and demanding environments.
**Intensive green roofs**

Intensive green roof profiles can range from 200mm to over 1m deep. This increases the volume of growing media available for root development and water-holding capacity and greatly extends the variety of plants that can be grown. The additional weight demands a stronger physical roof structure than extensive green roofs but allows for foot traffic. Intensive green roof gardens can be as richly planted and landscaped as ground level gardens. They require the same level of maintenance as conventional gardens.

**Intensive green roof characteristics**

- Deep growing medium — 200mm or greater
- Requires stronger roof structure
- Weight 180–500kg/m² or more
- Wide range of plantings possible, from groundcover to trees
- Suitable for access and use as roof garden — wide scope for design and multiple uses
- Relatively expensive due to structural requirements
- Substantial thermal and acoustic insulation benefits
- Difficult to retrofit on existing buildings
- Regular maintenance required

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 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. Like green roofs, green walls at their simplest can be made on a low-tech DIY basis or be quite sophisticated and expensive. An increasing number of proprietary green wall systems incorporate irrigation systems.

*Green walls may be incorporated into the cooling strategy of a house and may even be designed as part of a water treatment system.*

**Green wall types**

- Green façades — pots with vines on trellises
- Active — with soil/growing medium running up wall
- Passive — epiphytes

**Recently established succulents on proprietary green wall system.**
Materials
Green roofs and walls

Performance summary

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 groundcover 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 landscaped ‘roof gardens’ can radically change a building’s roofline.

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 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 effects.

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 carefully clipped hedge) or wild and funky.

Green walls can humidify and oxygenate the air and, depending on the plant species, further improve indoor air quality by acting as filters, trapping dust and absorbing pollutants such as volatile organic compounds that may be given off by carpets, paints, adhesives and sealants.

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.

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

Green roofs and walls

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 and shading 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 higher 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 and shading for the building. 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; they would, in any case, vary according to the degree of saturation of the growing medium.

*Green roofs provide significant thermal insulation and shading for a building.*

In Australia, the energy benefits of green roofs are most pronounced in their ability to reduce summer cooling demands. Their contribution to insulating and shading buildings can help significantly in reducing energy consumption and carbon pollution. However, it is difficult to obtain accredited insulation values for green roof construction. For specifying and code compliance purposes, thermal insulation standards should be met by conventional means with the additional insulation value of a green roof regarded as a bonus (an energy assessor may be able to give some credit for a green roof).

Green roofs can extend 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. 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 can be relatively costly so key structural considerations include:

- longevity of the structure
- appropriate drainage
- waterproofing.

Fire and vermin resistance

The soil used in green roof construction is fire resistant. The different kinds of vegetation that might be found on a green roof range from shallow-rooted succulents, which burn poorly and offer good fire resistance, to more substantial plants on intensive roofs that can include shrubs and trees. Although 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 rooftop vegetation to support ongoing conflagration is limited and a green roof can be expected to have good fire resistance, particularly if it is vegetated with succulents or when the growing medium is saturated. There are no relevant Australian...
Materials
Green roofs and walls

codes as yet, but as an example, German building codes require a 600mm fire break in the planting every 40m. Fire-activated sprinkler irrigation can further reduce risk.

Vermin are animals 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 greater biodiversity and less imbalance between humans and other fauna.

Breathability and toxicity

Vegetation in urban areas can filter out fine airborne particles that then wash off into the soil and foliage can absorb many 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% 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 help remove harmful pollution from runoff into aquatic ecosystems.

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

Researchers at the Welsh School of Architecture, Cardiff University, concluded that green roofs and walls could cool the local climate around a building in a city by 3.6–11.3°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% more than from panels on asphalt or gravel covered roofs.

Electromagnetic radiation can be reduced by more than 99% 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, while a large US vehicle manufacturer has a bee farm on the 4ha green roof above one of its factories.

Green roofs can reduce the costs of dealing with the nationwide increase in peak rainfall events associated with climate change in Australia by retaining stormwater and slowing rainfall runoff. Student research at the University of Queensland has shown runoff reductions of up to 42% achieved with only 100mm of soil planted with moderate growth turf; 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 that act as filters, removing nutrients, polluting compounds and organic matter from the water. (see Wastewater reuse)
Ease of building, 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 investment returns. However the long-term returns are potentially excellent. Without legislation to encourage green roof construction, Australian uptake will be driven by rating systems that value green roofs, their environmental benefits, 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, a green roof typically has seven layers:

▪ waterproofing membrane (built-up roof, single-ply membrane or fluid-applied membrane; modified bitumen or plastic sheeting is most typical)
▪ root barrier (polyethylene sheeting, copper or copper compounds in the membrane)
▪ insulation (optional)
▪ drainage layer (synthetic drainage mesh, granular aggregate)
▪ filter fabric (geotextile)
▪ growing medium — also known as planting medium or substrate (manufactured soil, crushed brick or other inorganic material which may be supplemented with organic material such as coconut fibre or coir)
▪ 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 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 through 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 consider:
▪ the climate zone (see 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

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

The structural and waterproofing elements of green roofs, properly installed, require little maintenance. As with all aspects of building, good construction detailing reduces the risk of failures and facilitates access for repairs, e.g. in the unlikely event of leaks.

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.
Earth-sheltered houses

Building with earth is one of the oldest types of construction, dating back to prehistory. Building up banks of earth (berming) is one of the simplest ways to provide the basics of shelter. Using turf is one of the oldest known ways of creating a long-lasting, low-maintenance, waterproof roof covering. Together, these techniques form the basis of earth-sheltered housing which, in its modern form, is a sophisticated method of building with strong environmental credentials.

Appearance

Often built into hillsides, earth-sheltered homes are usually purposely designed to ‘disappear’ into the environment and have a minimal visual impact. The earth is covered with vegetation and often the only sign that there is a house comes from windows facing the sun and views.

The perception that ‘underground’ homes are dark and gloomy is something of a myth as earth-sheltered houses are designed to bring light into rooms as much as any normal home. The main difference is that if a house is set into a slope, most if not all of its windows are on the downslope side of the building, usually facing the solar direction. Other rooms may be day-lit through skylights or ‘borrowed’ light from sunlit rooms.

Structural capability

Earth-sheltered buildings must be well engineered. Most of the ‘external’ walls of earth-sheltered houses act as retaining walls and need to possess sufficient structural capacity and construction detailing to deal with the large sideways physical forces and hydraulic pressure that come from building into the earth.

Their roofs are essentially green roofs and usually deep (intensive) roofs that need considerably more structural support than the more shallow extensive type. Green roofs are usually covered with an artificial soil or growing medium to minimise roof loads but earth-sheltered homes often use heavier natural soil as a continuation of the indigenous site conditions.

Thermal mass

A key principle of earth-sheltered housing is to use the enormous thermal mass of the earth to help maintain a steady and comfortable temperature in the home. For this to work best, the walls of the building should connect directly to the earth. In practice, waterproof membranes and insulation layers may compromise some of that connectivity. As a rule of thumb, the more-or-less continuous temperature of the ground ‘six feet under’ (approximately 1800mm) is the same as the annual aboveground mean temperature at any given site, i.e. between 17°C and 22°C in much of Australia. In places with lower deep soil temperatures (e.g. Melbourne and Tasmania) some insulation between the building and the earth may have some value in that it allows solar gain or heating to keep the home above the soil temperature without using much energy.

Insulation

Depending on the thickness of the soil, ground temperature, structure and other building elements, earth-sheltered construction can provide substantial thermal and acoustic insulation. The extent of that insulation for any given soil type or growing medium is poorly documented and the insulation given by earth roofs, for instance, may not be taken into account for the purpose of obtaining energy ratings for building approvals without using expert opinion.

Fire and vermin resistance

Although the vegetation that covers earth buildings is much more flammable than the soil that supports it, the plants could burn out completely and still not have a significant impact on the building. Earth is extremely resistant to fire.

Rather than harbour vermin, earth-sheltered structures support living systems of plants, micro-organisms and other creatures that do not attack the building structure; plant root barriers are a necessary part of the roof construction.

Durability and moisture resistance

The main structures of earth-sheltered buildings are not exposed to weather but do have to be protected against moisture penetration for many years. The waterproof membranes of the roofs and walls are protected by the earth that covers them, adding to their longevity.
Toxicity and environmental impacts

Like other dwelling types, earth-sheltered buildings can be constructed in many ways, using materials ranging from concrete and steel to timber, glass and plastic. The extent of toxicity and environmental impacts depends entirely on the specification. Although the principles of its construction are simple, the design of a modern, code-compliant, earth-sheltered house benefits from using the services of an architect or building designer with relevant experience.

Buildability

Although earth-sheltered homes are relatively rare in Australia, their buildability is equal to that of more conventional houses, and designers and builders who have built with this technique hold a substantial body of experience.

References and additional reading


Green Roofs Australasia. www.greenroofsaustralasia.com.au


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