

briefing note 2

briefing note contents

Green Roofs

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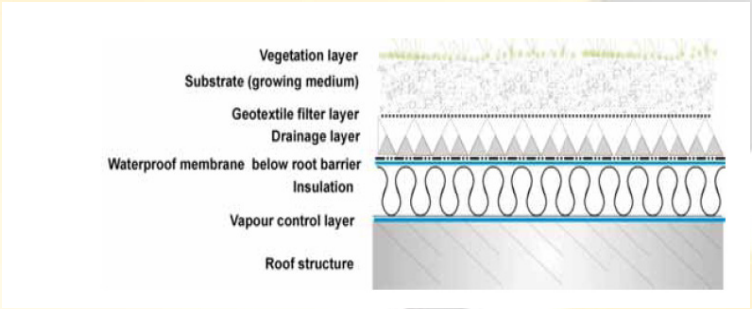
This Briefing Note was produced on behalf of Willmott Dixon by WD Re-Thinking Ltd

What is a Green Roof?

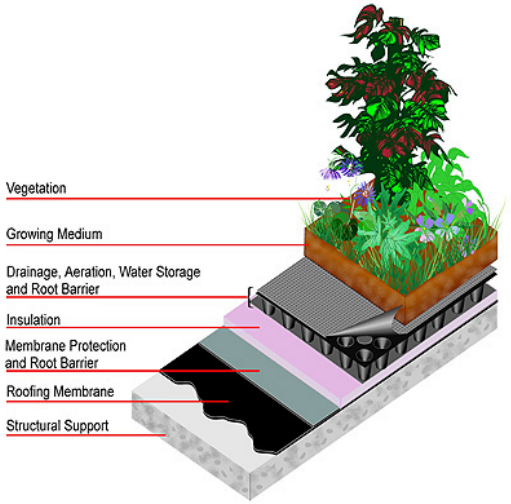
Green (or living) roofs are known as roofs that are purposely fitted or cultivated with vegetation. There are different types of green roof and it is important to understand that they provide different habitats, affect stormwater runoff to varying degrees, and impact on energy usage and thermal performance differently. They can also look very different and present different challenges during installation. They can be extensive (planted with simple plants such as sedum, or allowed to seed naturally, where they are called biodiverse roofs), or intensive (planted with shrubs and even trees). At present there are no specific British Standards relating to green roofs.

A green roof usually consists of the following:

- Vegetation, often specially selected for particular applications,
- Engineered growing medium, which may/or may not include soil.
- Landscape or filter cloth to contain the roots (root barrier) and the growing medium, while allowing for water penetration.
- A specialized drainage layer, sometimes with built-in water reservoirs.
- A waterproofing / roofing membrane, with an integral root repellent.
- Roof structure, with traditional insulation either above or below.



(A cross section of a typical green roof. CIRIA green roofs: An Introduction & overview benefits, 2008)



http://www.lid-stormwater.net/images/greenroof1.jpg

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Green Roof properties in more detail

Vegetation:
Type of planting depends on depth of the growing medium layer as well as other factor (see above) This can be created by using vegetation mats (e.g. sedum mats), through plug-planting pot grown plants into the substrate, by distributing seeds by hand or cuttings, or simply by natural colonisation.

Substrate/Growing medium:
This provides the mechanical strength – key properties include grain size, pore structure, water retention properties, air volume, weight and nutrient reserves. The soil needs to be stable, not prone to settlement, well aerated (even with water saturation) and free of weeds. A wide range of substrate types are available.

Drainage:
This layer controls the drainage properties of the roof in combination with the substrate i.e. it drains water off the roof, protects the root proof layer from being mechanically damaged, retains water for times of drought, and provides the substrate with a balanced supply of water and air. Drainage layers can be composed of either granular materials (e.g. sand and/or gravel, lava and pumice, crushed brick etc.) or modular/ sheet systems.

Insulation:
Further enhances the thermal properties of the roof build up, typically using a warm roof rigid insulation.

Root membrane:
This prevents plant roots from damaging the waterproofing. The membranes specification depends on the planned landscape and the slope of the roof. The root barrier could either be a biocide or a copper/ heavy grade polythene-based material.

Points to consider

Green roof systems can be placed on inverted, warm or cold roofs, in either a flat or pitched configuration. The most common arrangements are flat inverted or warm roofs.

It is important to make sure the roof structure can withstand the load, including the weight of fully grown plants and any temporary equipment that is likely to be placed on it.

Higher costs are associated with pitched roofs on account of the additional safety measures that may be required for construction and maintenance.

Many waterproofing systems can be used on green roofs. If the waterproofing layer is shielded from the sun, service life can be prolonged by between at least 10% and at most 100% (i.e. doubled).

It has been shown that cutting the risk of leakage is crucial to ensuring reasonable lifecycle costs. To avoid penetrations through the roof, the waterproofing layer should be checked to ensure that it is 150mm above the growing layer at abutments and an integrity test should be carried out on the waterproofing layer before laying the green roof. To ensure adequate

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drainage, flat roofs should be laid to a fall of 1:40. This avoids ponding along with the problems associated with it and should accommodate construction tolerances.

A separate root barrier may be required to protect the waterproofing membrane, especially if planting includes aggressive rhizomes. A waterproofing membrane can act as a root barrier and should comply with BS EN 13948, the standard for resistance to root penetration.

A drainage layer is also essential for planting and water attenuation. Options include porous mats, corrugated plastics sheets, or granular material.

Building materials are 'weathered' over time and require maintenance; one of the biggest 'wearing' factors is the expansion and contraction of the materials, often at different rates (i.e. steel v. brick, or glass) which 'wears' the building. A good and carefully designed green roof can address both the day to day internal environment issues, and the long-term decay of a buildings material elements by maintaining a steady microclimate at its surface.

The plants available to you depend on the depth of soil you create:

- 0–5 cm - Sedums, mosses and lichens.
- 5–10 cm - Short wildflower meadows, low-growing, drought-tolerant perennials, grasses, alpines and small bulbs.
- 10–20 cm - Mixtures of low or medium perennials, grasses, bulbs and annuals from dry habitats, wildflower meadows and hardy sub-shrubs.

Advantages and Disadvantages of Green Roofs

The application of vegetation and growing media gives some environmental benefits to a building; these are inherent to all green roofs, to varying degrees, which include:

- Providing additional insulation to the roof structure of and hence energy use in the building in both winter and summer (in the case of mechanical cooling). However it should be noted that additional benefits over roof build-ups meeting Building Regulations 2006 standards may not be that significant (Kumar and Kaushik, 2005; CIRIA, 2008).
- Retaining stormwater for small storm events (Carter and Rasmussen, 2006), benefiting Sustainable urban drainage system (SUDS) strategy.
- Increasing biodiversity and habitat in urban areas largely devoid of such space (Kim, 2004; Brenneisen, 2005).
- Improving ambient air quality (Clark et al., 2005).
- Act as noise reducers; depending on the thickness of the medium. (Van Renterghem & Botteldooren, 2008).
- Energy savings in existing buildings with poor quality insulation.
- Reduces urban heat Island effect.
- Promotes Biodiversity.

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There may even be realistic additional benefits provide by green roof applications in some circumstances (Peck et al., 1999)

- Accessibility and esthetical appeal for the building occupants
- Sound insulation
- Potential for urban agriculture.

The main disadvantages are:

- Increased initial capital cost of both the green roof system and the roof structure.
- Potentially increased maintenance, although this can be minimised with appropriate choice of roof systems.

Two types of system: Intensive and Extensive compared

Intensive green roof systems:

- > 6 inch (deep growing media)
- Diverse planting regime
- Good insulation properties
- Can simulate wildlife that was on the ground
- More aesthetic
- Longer membrane life
- High capital cost
- High maintenance
- High load on roof structure
- Usually needs irrigation

Extensive green roof systems:

- 2-6 inch (thin growing media)
- Drought tolerant plants (fewer plants will survive)
- Less expensive than Intensive (lower capital cost)
- Lower maintenance
- Lightweight
- Easy retrofit
- No irrigation needed
- Less aesthetic
- Less energy efficiency benefits
- Less storm water retention benefits.

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Type of Green Roof System	
Extensive system	**Intensive system**
Thin growing medium (2-6inch), little or no irrigation, stressful plant conditions (drought tolerant), low plant diversity, usually less aesthetic	Deep growing medium (usually soil, >6inch), favourable plant conditions, high plant diversity, often accessible, more aesthetic
ADVANTAGES	**ADVANTAGES**
• Lightweight, usually no roof reinforcement needed • Suitable for Large areas • Works on roofs with 0-30° slope • Low maintenance & long life giving cost advantage • Usually no requirement for irrigation & specialised drainage systems • Less technical expertise required • Usually can be retrofitted • Vegetation can grow spontaneously • Relatively low capital cost • Natural look	• Greater diversity of plant & habitats • Good insulation properties • Can simulate wildlife garden on roof • Very good aesthetics (if managed properly) • Often accessible, more diverse utilisation of roof space i.e. for recreation, growing food, as open space, allotments. • Greater energy efficiency • Greater storm water retention • Long membrane life
DISADVANTAGES	**DISADVANTAGES**
• Less energy efficiency benefits • Less storm water retention benefits • Limited plant choice • Usually no access for other use i.e. recreation • Not aesthetic to some, (still better than normal roof though) • High short term cost	• High weight loading on roof • Need for irrigation & drainage system, requiring energy, water, minerals • Even higher capital and maintenance cost than extensive • More complex systems and expertise

Advantages in detail

Sustainable drainage:

A typical extensive green roof will fully intercept between 50% and 75% of rainwater and will delay all surface run-off, reducing peak storm water flows and the scale of the rainwater installation required. The filtering action of plants in green roofs is also claimed to prevent pollutants such as nitrates, phosphates and particulates from entering water courses. Green roofs can reduce the chance of localized flooding, and relieve pressure on local drainage systems.

Substrate depth (mm)	State	Surface runoff (%)	Evapotranspiration (%)
50	Established	37	63
120	Established	28	72
100	New	58	42

(Water run-off information, from Schmidt in CIBSE, 2007)

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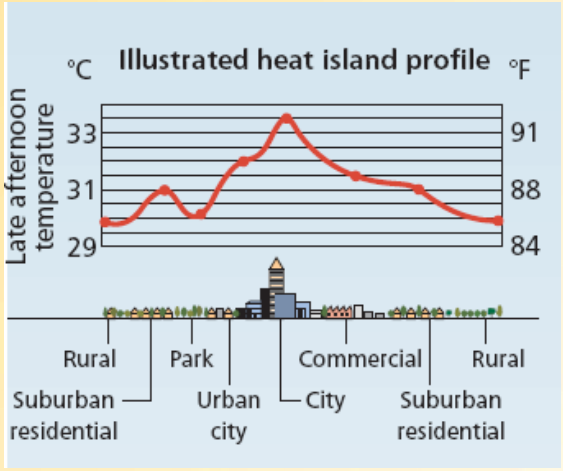
Microclimate:

A wide number of claims with respect to the positive effect of green roof vegetation on microclimate are made. These are cumulative and depend on the action of a large aggregate area of roof to make a noticeable difference. The beneficial outcomes include:

- Urban heat Island effect reduced (the temperature disparity between urbanised areas and surrounding rural areas)



(Sketch of an urban heat-island profile adapted from U.S. Environmental Protection Agency website)

- Direct absorption of nitrous oxide
- Direct local cooling in the immediate proximity of the roof, through the effects of evapo-transpiration
- Indirect cooling through the reduction of heat radiated into the air by building surfaces or held and released by a building's thermal mass
- Indirect reductions in the formation of photochemical smog due to reduced air temperatures and the absorption of airborne chemical compounds by the roof vegetation.

Biodiversity:

Green roofs provide opportunities to create biodiversity or, in some cases, to recreate environments that could be lost through redevelopment (i.e. replacing what was lost at ground level on the roof). The extent depends on the variety of planting, the depth of the growing medium and the similarity to local ecosystem. The roof can be designed to provide habitat for nesting birds and invertebrates as well as plant species. This could also be used as an attractive area for locals, and could possibly be used as an educational tool adding to the local community.

Building performance:

Aspects of building performance that provide direct payback to building owners include:

- Durability of the roofing membrane, where the green roof protects the roof membrane from exposure to UV and from heat ageing caused by thermal expansion and contraction
- Reduced energy costs (more significant in retrofit buildings). Soil acts as an insulant when dry, so may not be effective in providing insulation during wet heating seasons. Plant cover also contributes to reducing heat loss caused by wind. During summer months, diversion of solar heat gain into the thermal mass of the growing medium can reduce the heat energy stored in the building fabric that would otherwise later be released into occupied space, potentially increasing cooling loads. Results from Germany suggest

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that the energy saving is equivalent to 2 litres of fuel oil/ m^2 of green roof/year. Thus giving an incremental increase in cost saving in relation to fuel prices year on year.

Aesthetics:

The appearance of a green roof is likely to be an improvement on an uncovered, flat roof. Overall visual impact will be determined by the following:

- Time available to mature. Pre-grown blankets or scattered cuttings achieve coverage quickly but offer a less diverse range of plants
- Shallow sedum blankets can only support a limited number of plants
- Extensive roofs can die back during extended dry periods
- All roofs need maintenance, but the requirement increases as the depth of the growing medium increases, and as planting becomes more complex.
- The presence of a green roof may also add to the amenity value and the property value of a development.
  (Building Magazine, 2006)

Maintenance issues:

There will however be some maintenance issues which will depend on the planting and microclimate in the area of the building. These will probably include, and will result in some additional cost:

- Keeping drainage outlets clear
- Inspecting the waterproofing layer where visible
- Watering, if required (automatic irrigation - higher capital costs)
- Weeding. Plant replacement and removal of unwanted material is labour-intensive but important to maintain the amenity, possible community interaction here.
- Fertilising: Annual application of slow-release type for extensive green roofs. Intensive planting may incorporate nutrient-rich soils with specific fertilisation requirements.

Water Attenuation

Water attenuation depends on a few factors, the planting regime, slope of roof, microclimate and type of green roof installed.

A study on the effect of roof sloping by (Getter, A et al 2007) showed that green roof slope has an effect on runoff retention quantities. Retention values decreased as slope increased and were significant for slopes between 2% and 15% as well as between 2% and 25%.

Mean retention was least at the 25% slope (76.4%) and greatest at the 2% slope (85.6%)

All of these greened slopes had less runoff than traditional black roofs

It was also noted that Retention on any roof depends on rainfall distribution throughout the year, the intensity of each event, ambient air temperatures, plant selection, and the influence of local environmental conditions on evapotranspiration.

The following table shows water retention for differing roof types, again this is just a rough guide.

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Substrate depth (mm)	Vegetation	Average annual water retention (%)	Average annual rainfall run off (%)
20-40	Moss, sedums	40	60
40-60	Sedums & moss	45	55
60-100	Sedums, moss & herbs	50	50
100-150	Sedums, herbs & grass	55	45
150-200	Grass & herbs	60	40

(Water retention in Extensive green roofs, based on 650-800mm rainfall, FLL 2004)

Type	Thickness*(mm)	Dead Load** ($kN/m^{2)}$	Rainfall Retention
Extensive	50	0.7	50%+
Semi-Intensive	200	5	70%
Intensive	600	10	n/a
*overall thickness for growing medium and drainage layer			
**Dead load based on fully saturated soil and drainage layer			

(Loadings for general green roof type http://www.building.co.uk/story.asp?storycode=3069718)

Loading Guide (saturated weights)

Loadings will vary depending on the roof type and careful considerations will need to be made in the design stage of the green roof. Below is a rough guide to some loadings for differing roof types from 2 different sources:

- Extensive Green roof: 60–150 Kg/m^2
- Intensive green Roof: 200–500 Kg/m^2

(source www.greenroofs.com)

Type of Roof System	Support Load / $kg.m^{-2}$
Gravel surface	90-150
Standard Tiled roof	Approx 150
Paving slabs	160-220
Extensive green roof	60-150
Intensive green roof	200-500

(Loadings for green roof systems, Firth and Gedge, 2005)

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Economic

A green roof will, initially at least, cost more than a conventional roof. Costs depend on the type of green roof specified and it is important to remember that the £/m^2 cost of a small green roof will be greater than that of a large one. However, specifying green roofs can reduce the amount of final attenuation capacity required in a SUDS system, and the cooling effect of green roofs will reduce energy use during the lifetime of the building.

Type of Green roof finish	Cost per m^2 (£)	Installation Issues	Maintenance cost
75mm substrate sedum plug roof	25	Slower installation as plants installed separately	Quite high over first two years while systems bed in
75mm substrate sedum, hydro seeded	20-25	Fast installation; can take two years for plants to mature	Quite high over first two years while systems bed in
75mm natural/biodiversity	20-25	Fast installation; can take many years for plants to establish	Low
20-30mm sedum mat/blanket	40-50	Fast installation: immediate green roof effect	Low-medium

(Average cost of differing green roof types*, CIBSE, 2007)

*Note: this table is a guideline only. It does not include installation costs; these will need to be ascertained to understand the total cost of the roof design as specified. It is possible to offset some of the costs of a green roof at the design and specification stage. For example, an inverted roof system requires ballast, either shingle or paving slabs, which can be replaced by a 75 mm substrate based green roof. Ballast paving costs in the region of £10–17 per m^2. If a substrate based biodiverse roof at a cost of £20–25 per m^2 replaces paving at £17 per m^2, then the additional cost of a green roof is reduced to £3–8 per m^2. As green roofs are considered as a source control component of SUDS, savings can be made further down the SUDS management train when a green roof is specified. These savings can be significant if applied to many roofs across large developments, especially as most downstream SUDS solutions such as swales, detention basins and balancing ponds require land grab, whereas green roofs do not. (CIBSE KS11, 2007)

Whole-life cost (WLC) considerations:

There are several environmental benefits that could be offset against the capital and maintenance costs of a green roof. It is not always straightforward to translate these into monetary value for a whole-life cost assessment, but some are mentioned in the Code for Sustainable Homes as:

- Water attenuation
- Increased amenity space
- The absorption of airborne particles
- Increase in local biodiversity.

Cost mitigation measure could be achieved if the plants and or soil / aggregates can be reused from the development site.

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In Germany, it is estimated that the cost to install a green roof and maintain it over 40 years is about 43 (£29) per m^2, compared to a possible saving of 70 (£48) per m^2 from the reduced maintenance, energy saving, city water fee (saving from storm-water runoff) and increased life (Herman, R, 2003)
There is a lot of variation in cost for differing types of green roof and there are a few products available from differing manufactures. This has made it difficult to work out a WLC at this stage. Some WLC considerations are described below:

Extended Roof Life:
Green roof systems provide protection to roofing membranes from the effects of UV light, mechanical damage, high thermal temperature changes, e.g. freeze-thaw action, and therefore lead to a longer material life span. It is generally accepted that a greened roof can approximately double the material life. 'Derbigum', a commercial waterproofing system, has a 30-year life; with an extensive green roof system [cross brick/sedums] this would have a ~60-year life. This results in a cost benefit to the client over the years

Fuel saving:
Results from Germany have estimated that the energy saving is equivalent to 2 litres of fuel oil/m^2 of green roof/yr. They also have additional benefits such as reducing the heating and cooling requirements of a building (i.e. reduces air condition use in summer), thus reducing energy consumption.

Cost savings through the reuse of secondary aggregates:
The reuse of local aggregates can provide a cost saving during the construction of roof(s) within a development. The roof needs to work though, so this is only an option where the soil/aggregate is suitable as a growing medium and is capable of being supported by the roof in wet conditions. Growing media when bought new is approximately £10 -£15/m^2. Although there will be a cost incurred if materials such as brick and concrete are used from site in terms of crushing to the required grade, screening and transportation within site this will be minimal. A 1000m^2 green roof could potentially save the developer approximately £10,000 off the cost of the materials needed on the green roof, thus reducing its cost and making it more viable in the short term. This will not be possible for every site but should still be a consideration when planning a green roof installation. Hard landscaping is required to weigh down floating insulation. This is replaced by the growing medium if a green roof is used. So this method also makes green roofs more viable when inverted roofs are constructed.

Studies have found that green roofs provide significant environmental benefit over a traditional roof relative to the life cycle and embodied energy of its materials (Alcazar and Bass, 2006;Coffman and Martin, 2004; Kosareo and Ries, 2006).

According to English Nature's Green roof Report (2003) the price of an extensive green roof system (Kalzip Nature Roof) is approximately £98 square metre. Prices may rise to £130/m^2 for a small roof (150 m^2) and fall to £85/m^2 for a larger roof (2500m^2).

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Additional costing table from 'Building' magazine

A discount rate of 3% is used to calculate net present values. Costs are for growing layer and planting only, including continuing maintenance: weeding, fertilisation, allowance for replacement substrate, planting and occasional irrigation. Structure, waterproofing, insulation and drainage system are excluded. Costs are indicative and represent the average of a range.

No attempt has been made to include environmental benefits. A cost analysis based on project-specific information is essential for a realistic best-value appraisal, including environmental trade-offs. The cost for small roofs would be proportionately higher. Planting and growing media are not given service lives as their performance is related to maintenance. The lifecycle costing allows for a major overhaul between years 20–30. BLP Insurance provides latent defect warranties for buildings www.blpinsurance.com.

The costing table below looks into green roof costs over the long term (a 60 year period)

Specification options: green roofs Capital cost/Net present value for 60 years		
	£/m²	£/m²
Extensive green roofs		
Sedum mat pre-grown 20-30mm substrate	45	55
Sedum pre-grown plug planting 75mm substrate	33	42
Intensive green roofs		
Semi-intensive grass, herbaceous plants, 120–200mm substrate	30	44
Intensive low-lying shrubs and coppices, 150–250mm substrate	35	51

The following costs are for green roofs with areas ranging from 100 to 1000 m². The rates include the specialist contractor's costs, but exclude allowances for main contractors' preliminaries and overheads and profit. Costs are current in June 2006 based on an average UK location. Rates are based on the surface area of the green roof.

B - Indicative costs of green roof	
Sedum blanket only	£35–40/m²
Sedum blanket with drainage layer and filter fleece	£45–65/m²
Sedum blanket on filter fleece and drainage layers, capping layer and vapour barrier	£80-115/m²
Extra for insulation	£50/m²
Extra for waterproof membrane and vapour barrier	£30-45/m²
250 mm thick growing medium on drainage board, root membranes and insulation; turf	£85–100/m²
225 mm thick growing medium on filter fleece and LDPE drainage core; plug and hydroseed planting	£50–60/m²

The costings for larger roofs harder to find, generally accepted that cost come down with a larger roof size and size of green roof.

(Costings from Specifier 03 October 2008)

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Summary

It appears that with careful consideration and design at an early stage, that green roof systems are a viable option over their predicted whole life cycle depending on the roof type replaced, their location, type and size. Economic analysis is difficult to analyze due to the many factors involved in WLC, in terms of energy savings (perhaps the easiest to calculate) as cost of fuel increases green roofs will become a more attractive proposition in the future due to increase savings made through thermal efficiency. Germany seems to be pioneering in their use of green roofs. They have already shown that increased uptake of green roofs has reduce costs.

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- The following document was mentioned in the CIBSE guide as a good standard to follow if implementing a green roof. I could not find a copy of it without having to pay for it. It is referred to in this document as the FLL. *Guidelines for the Planning, Execution and Upkeep of Green-Roof Sites* (English version) (Bonn, Germany: Forschüngsgesellschaft Landschaftsentwicklung Landschaftbau e.V.) (2002) (ISBN 3-934484-59-x)

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