GREEN ROOFS

Green roofs, also known as vegetated roofs, are built utilizing plants adapted for rooftop conditions. This low-impact development (LID) technique absorbs rainfall that would otherwise be wasted as stormwater runoff and helps compensate for the vegetated footprint eliminated during construction. There are two types of green roofs, intensive and extensive.

Extensive green roofs

Extensive green roofs are characterized by their relatively thin soil (maximum of six inches) and the types of plants used (typically sedums, succulents, and hardy perennials). Extensive green roofs are not typically accessed except for maintenance purposes, unless walkways or plazas are incorporated into the design.

Intensive green roofs

Intensive green roofs are heavier vegetated roof systems characterized by thick soil media (12 inches or more) and the potential for growing a variety of plants, from sedums to small trees. Intensive green roofs often support pedestrian access. They can be designed as public places or home amenities, with walkways, terraces, plazas, or seating areas. Because of their weight, intensive green roofs require strong structural support.

How green roofs work

When it rains, water filters through the soil medium and is absorbed by the plants. Eventually, it is returned to the atmosphere through transpiration. This process significantly reduces the amount of stormwater runoff from a developed site and improves the quality of the runoff that is released.

Green roofs and low-impact development

Green roofs offer many opportunities for education on low-impact development techniques, such as stormwater management and native plants.

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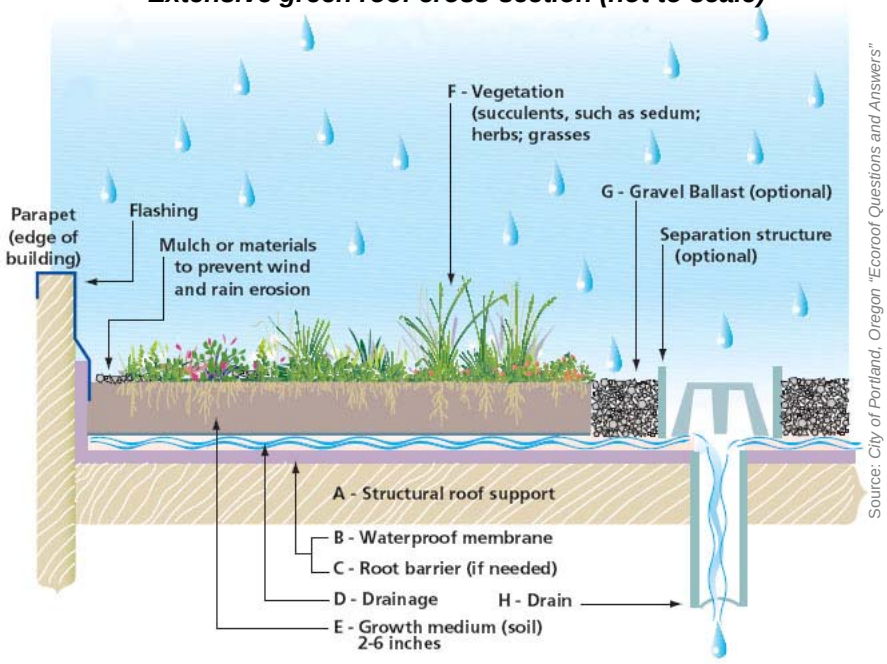
Extensive Green Roof on a Furman Company Office Building (Greenville, SC)

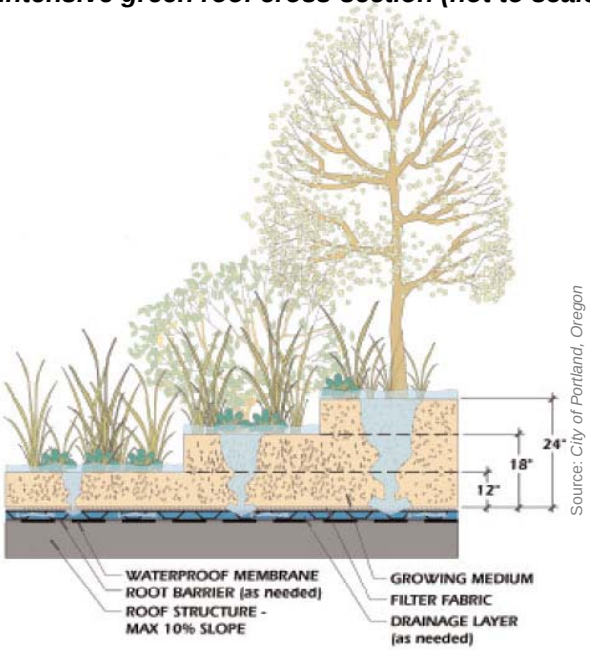
Intensive Green Roof on Riverside High School (Greer, SC)

Figure 1
Extensive green roof cross-section (not to scale)



Source: *City of Portland, Oregon "Ecoroof Questions and Answers"*

Figure 2
Intensive green roof cross-section (not to scale)



Source: *City of Portland, Oregon*

Waterproof Membrane

The waterproof membrane is the most important factor for the long-term success of the green roof because it protects the roof sheathing from climatic conditions, including UV light and rain, which ultimately lead to the deterioration of the roof. The membrane rests on top of the roof sheathing and can be made of a variety of materials, including modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC. Some of these materials come in sheets or rolls and some are in liquid form. Before installing a green roof in a retrofit project, ensure that there are no leaks in the original roof sheathing and determine if any additional structural support is necessary.

Root Barrier (if needed)

Root barriers are made of dense materials that inhibit root penetration. The need for a root barrier depends on the type of waterproof membrane used. For example, some membranes, such as modified asphalt membranes, are organic and can be penetrated by roots seeking nutrients. Other membranes, such as reinforced PVC, are synthetic and prevent root penetration. Most often, organic membranes require root barriers, while synthetic membranes do not.

Drainage Layer (if needed)

The drainage layer is used to remove any excess water from the roof that is not absorbed by plants. The drainage layer is typically an underdrain composed of perforated plastic sheets or a thin layer of gravel. Some pitched roofs and small, flat roofs with shallow layers may combine the drainage and filter layers (extensive roofs only).

Filter Layer

The filter layer is designed to hold the soil in place and to prevent fine materials from clogging the drainage layer below. Air and water flow through the filter while protecting the underdrain. The filter layer is typically made of durable geosynthetic fabric that allows water to flow through it.

Soil Media

For extensive roofs, the soil medium is generally two to six inches thick, while intensive roof soil is typically 12 inches thick or more to allow for deep root systems. The engineered soil medium is often composed of inorganic absorbent material such as perlite, clay shale, pumice, or crushed terracotta, with a very small organic content. Typically, only five percent organic soil is used because too much organic content results in problems with settling, nutrient export, and accelerated plant growth.

Vegetation

Vegetation on extensive green roofs typically consists of plants that are hardy, low-growing, drought-resistant, and fire-resistant. The plants must be able to withstand heat, cold, and high winds. In addition, the plants should be low-maintenance, requiring little to no mowing, trimming, fertilizers, or pesticides. Some plants commonly used are sedum, succulents, or hardy perennials. Grasses are less common because, in order to survive dry periods, they require irrigation or a deeper soil substrate that retains more water. Vegetation may be planted as mats, plugs, potted plants, sprigs (cuttings), or seeds.

Intensive green roofs allow for a wide variety of vegetation, including perennials, sedums, shrubs, and even trees. The thick soil medium allows for vegetation with deeper root systems. Because a wider range of vegetation can be incorporated into intensive green roofs, more maintenance activities, including irrigation and weeding, are often required. To reduce maintenance, the use of species native to Upstate South Carolina should be incorporated into the design.

Gravel Ballast (if needed)

Gravel ballast is sometimes placed at the perimeter of the roof and around air vents, skylights, mechanical systems, chimneys, or other vertical elements in order to protect these features, as well as to provide maintenance access. Extensive green roofs typically require little to no ballast because access to the roof is only for maintenance purposes, while intensive green roofs require more ballast because the roof is accessed often.

Design component information adapted from the Massachusetts Low Impact Development Toolkit: Green Roofs Fact Sheet

Extensive Green Roof
Norfolk, Virginia, Residence

This residence borders the Lafayette River, a tributary of the Chesapeake Bay. Because of the house's close proximity to the river, it was important to the owner to reduce negative stormwater impacts. An extensive green roof was installed to solve this problem. Not only does the green roof reduce runoff volume, it also filters rainwater so what does run off is cleaner.

BENEFITS

Runoff Quantity Control

Green roofs absorb much of the water that falls on them, resulting in a reduction of stormwater runoff. In summer, depending on the type of plants and depth of growing medium, green roofs retain 70 to 90% of precipitation; in winter they retain between 25 and 40%. For example, a grass roof with a 1.6 to 7.9 inch layer of growing medium can hold 3.9 to 5.9 inches of water. In addition, green roofs delay the speed at which runoff occurs, thus reducing stress on storm sewer systems and streams at peak flow periods.

Longer Roof Life

It is estimated that green roofs will last up to twenty years longer than conventional roofs. The roof membrane is protected by the multiple layers on top of it, which results in a longer lifespan for the membrane. Additionally, green roofs moderate the temperature extremes of a roof surface and prevent it from being exposed to UV radiation that could accelerate its breakdown. This too helps extend the lifespan of the roof.

Lower Heating and Cooling Costs

Lower costs related to heating and cooling can also occur as a result of the green roof's insulating properties. A green roof system prevents heat from moving through the roof. Roofs that have a low density/high moisture soil media and plants with a high leaf area index maximize the insulation properties of the roof. For example, Environment Canada found that a typical one-story building with a grass roof and 3.9 inches of growing medium would result in a 25% reduction in summer cooling needs. Another study in Canada found that a six-inch extensive green roof reduced heat gains by 95% and heat losses by 26% compared to a conventional roof.

Intensive Green Roof
Atlanta, Georgia, City Hall

Completed in 2003, the green roof on Atlanta's City Hall is adjacent to the building's cafeteria and is accessible to the public as well as the workers. The vegetation is predominantly a mix of sedums and perennials.

The City of Atlanta implemented this green roof project in hopes of contributing to the growing body of knowledge of green roof benefits, including increased energy efficiency, stormwater retention, and the extension of roof life span. In addition, they hope to simply increase awareness of green roof technology.

Temperature Reduction

Green roofs help reduce the "urban heat island effect" by helping to compensate for the vegetated footprint lost during construction. Plants use heat from their surroundings in the process of evapotranspiration. Cities are typically much warmer than rural areas because of their extensive hard and reflective surfaces, such as roofs and pavement, which absorb solar radiation and re-radiate it as heat. Green roofs replace conventional rooftops, substituting hard, reflective surfaces with plants, and thus reduce the "urban heat island effect," or the difference in temperature between a city and the surrounding countryside.

Sound Insulation

Soil, plants, and the air within the soil absorb, reflect, and deflect sound waves. The soil media typically blocks lower sound frequencies while plants block higher frequencies. For example, a green roof with a 4.7-inch substrate layer can reduce sound by 40 decibels; a 7.9-inch substrate layer can reduce sound by 46 to 50 decibels.

Additional Benefits

Green roofs can be designed to be aesthetically pleasing. With proper plants and design, a roof can be an attractive place.

Green roofs can be wildlife habitats. Native plants and trees often attract a variety of birds and butterflies to the rooftop.

Additionally, **green roofs offer many opportunities to be utilized for educational purposes.** Green roofs can be used to teach community members about the stormwater management benefits of low-impact development techniques. They can also be a useful source for learning about native vegetation, since green roofs almost always incorporate native plants into their sites. The roof itself can be used as an outdoor classroom, as is the case at Riverside High School in Greer, South Carolina.

"Benefits" adapted from Green Roofs for Healthy Cities.

SITE CONSIDERATIONS

	Extensive Green Roof	Intensive Green Roof
Acceptable sites	Residential, commercial, municipal, industrial sites; both retrofit and new sites.	Residential, commercial, municipal, industrial sites; both retrofit and new sites.
Roof size	Can vary significantly, from small residential tool shed to large commercial or industrial building.	Can vary significantly, from larger residential projects to large commercial, municipal, or industrial projects.
Slope of roof	Can use on flat or pitched roofs with up to 25% slope (slopes greater than 25% will require a stabilization system to prevent gravity creep of heavier materials; slopes less than 2% may require special drainage to avoid waterlogged soil).	Can use on flat or pitched roofs with up to 10% slope.
Roof strength	Must be able to hold 10 to 25 pounds per square foot when saturated.	Must be able to hold 80 to 150 pounds per square foot when saturated.
Access	Must include maintenance access in the design, so that any watering, clean-up, or inspection can take place easily and without concern for safety.	Must include maintenance access in the design, so that any watering, clean-up, or inspection can take place easily and without concern for safety.
Special considerations	Must include downspouts or drainage system; may want to consider draining to rainwater harvesting system, such as rain barrel or rain cistern, or to other bioretention area, such as rain garden or swale.	Must include irrigation system. Must include drainage system; may want to consider draining water to rainwater harvesting system, such as rain barrel or rain cistern, or to other bioretention area, such as rain garden or swale.

Intensive Green Roof on Parking Garage
Public Square in Nashville, Tennessee

In 2003, the City of Nashville began renovating the Nashville Metro Courthouse Complex. Included in this renovation was a five-level subterranean parking lot with a 2.5 acre intensive green roof. The roof was designed to be a public square for all citizens to use and enjoy.

The roof also effectively manages stormwater. Not only does the roof reduce stormwater runoff, it also captures rainwater in a 57,000 gallon tank for future use. After being filtered, this water supplies the high-efficiency irrigation system with re-circulated water. Only in times of drought does potable water have to be added to this supply.

Extensive Green Roof
Ford Motor Company's River Rouge Plant, Dearborn, Michigan

The 454,000 square foot roof is part of a comprehensive effort to revitalize the historic Ford Rouge Centre complex as a model for 21st Century sustainable manufacturing and is a significant component of a site-wide 600-acre stormwater management system. The roof is a key component of Ford's visitor education program that highlights environmentally-friendly site and building design.

MAINTENANCE

Schedule	Maintenance activity (intensive and extensive green roofs)
Establishment period (typically first six months)	▪ Irrigation (either through hand-watering or an automated irrigation system) is often needed at least once a week, until plants are established. ▪ Weeding and mulching may be needed during establishment, depending on planting method.
As needed	▪ For extensive roofs, irrigation might be necessary (either through hand-watering or an automated irrigation system) during drought conditions. Some form of regular irrigation is usually necessary for intensive roofs, especially during drought conditions. ▪ Health and coverage of vegetation must be checked periodically; some replacement and filling may be necessary. ▪ Most extensive green roofs are designed so as not to require trimming, but weeding and mulching might be necessary periodically; weeding and mulching of intensive roofs will be necessary occasionally.
Semi-annually	▪ Ensure drain inlets are not blocked to avoid leaks and/or damage to the plants. ▪ Vegetation (not including sedum and succulents) might need to be watered, mowed and/or maintained to prevent fire hazard. ▪ Fertilization is occasionally needed to prevent acidification of the thin soil layer.
Annually	▪ Check for leaks (though green roofs are less likely to leak than conventional roofs). Areas where occasional leak inspections are necessary are abutting vertical walls, roof vent pipes, outlets, air conditioning units, and perimeter areas.
Roof replacement (ecoroofs often last over 40 years)	▪ Remove and stockpile the vegetation, growth medium, irrigation pipes, and drainage layers. ▪ Remove and replace the waterproof membrane. ▪ Reinstall stockpiled vegetation, growth medium, irrigation pipes, drainage layers.

Source: City of Portland, Oregon – "Ecoroof Questions and Answers"; LID Center, Inc.

LID IN THE UPSTATE

Furman Company Office Building Greenville, South Carolina

Furman Company green roof during establishment period

In 2004, the Furman Company office building in Greenville, South Carolina was in need of a new roof. The owner was interested in green roof technology, particularly its stormwater management benefits, potential energy savings, and attention his company might receive for having one of the first green roofs in the area. The project involved removing the conventional roof system (made of gypsum, polyurethane foam, and aggregate) and installing a two-ply Modified Bituminous System distributed by Building Logics. Pre-grown vegetation mats were installed in May 2004 after being chosen for their ease of installation. However, by the end of the summer, the mats were failing; almost all of the plants had died except those in shade. The builders decided that the pre-grown mats did not do well in the intense heat and dry conditions of Upstate South Carolina. Although the plant supplier was unable to help find a solution, Building Logics, the roof supplier, provided new growing media, plants, and labor in September 2004. By June 2005, the roof was 70% covered and thriving. So far, the owner has been very satisfied with the green roof.

COST ESTIMATE

	Extensive Green Roof	Intensive Green Roof	Conventional Roof
New construction (including structural support)	$10-15/square foot	$16-25/square foot	$3-9/square foot
Re-roofing	$15-25/square foot (replacement typically every 40 years)	$20-35/square foot (replacement typically every 40 years)	$5-20/square foot (replacement typically every 20 years)
Utility costs	Can result in 20 to 30% reduction in annual cooling costs	Can result in 20 to 30% reduction in annual cooling costs	Standard energy costs apply

Adapted from City of Portland, Oregon – "Ecoroof Questions and Answers" and Greenroofs.com

Cost considerations

- Though ecoroofs are initially more expensive than conventional roofs, **they are competitive on a life-cycle basis due to reduced maintenance and replacement costs.**
  - Maintenance costs are minimal beginning about two years after installation.
  - Because green roof replacement occurs once about every 40 years instead of every 20 years as with conventional roofs, replacement costs are significantly reduced.
- Soil medium and plant components are often the highest costs associated with green roof construction.
- Green roof retrofit projects will likely be more expensive due to the replacement cost of the conventional roof and the consideration of structural/site limitations, such as strength and slope of the existing roof.
- As the ecoroof market expands, prices may decrease.

Riverside High School
Greer, South Carolina

LID IN THE UPSTATE

Three years ago, Riverside High School began the design process for its new school building. The architect suggested that the building be LEED certified, and those involved in the planning process accepted the challenge. The building, completed in 2005, incorporates green-building features such as motion-sensor lights, south-facing windows, and waterless urinals. The building also has an accessible intensive green roof that can be used for educational purposes. Not only can students learn about the benefits of green roofs and varieties of native plants, but they can also learn about data collection via a weather center and water collection device. The roof itself is generally maintenance-free, with only occasional fertilizing and weeding required. The rainwater that falls onto the planters is absorbed by plants and soil, while the water that falls on the tiles in between planters is directed to an underdrain connected to the school's drainage system. So far, the system has worked successfully, and the school is very pleased with the roof and the building as a whole.

ADDITIONAL LINKS

1. Low-Impact Development Center, Inc.
   (http://www.lid-stormwater.net/lid_techniques.htm)
   - ❖ Offers helpful information about green roof benefits, maintenance, specifications and sizing requirements, and costs
   - ❖ Includes sample engineering drawings
2. Green Roofs for Healthy Cities
   (http://www.greenroofs.org/)
   - ❖ Includes "About green roofs" page with extensive information about green roof benefits and FAQs
   - ❖ Additional information about research, conferences, awards, and more is provided
3. Greenroofs.com
   (http://www.greenroofs.com/)
   - ❖ Offers helpful information in "Greenroofs101" about advantages, components, FAQs, applications, and how-to's
   - ❖ Includes "Projects" section with comprehensive, searchable list of green roof projects around the world
4. Lower Columbia River Field Guide to Water Quality Friendly Development
   (http://www.lcrep.org/fieldguide/techniques.htm)
   - ❖ Provides numerous low-impact development fact sheets on a variety of techniques, including ecoroofs

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