

Low Impact Development strategies use careful site design and decentralized stormwater management to reduce the environmental footprint of new growth. This approach improves water quality, minimizes the need for expensive pipe-and-pond stormwater systems, and creates more attractive developments.

## MASSACHUSETTS LOW IMPACT DEVELOPMENT TOOLKIT

### FACT SHEET #9

# GREEN ROOFS



### Overview

A green roof is a low-maintenance vegetated roof system that stores rainwater in a lightweight engineered soil medium, where the water is taken up by plants and transpired into the air. As a result, much less water runs off the roof, as compared to conventional rooftops. Green roofs have been in use in Europe for more than 30 years; they are easy to incorporate into new construction, and can even be used on many existing buildings.

Green roofs provide an extra layer of insulation that reduces heating and cooling costs, and they are likely to last much longer than conventional roofs, since the roofing material itself is shielded from ultraviolet light and thermal stress. The vegetation on green roofs also improves air quality, enhances the appearance of the building, and reduces the urban “heat island” effect.

There are two distinct types of green roofs: extensive green roofs require less than 6” of soil medium and support mostly herbaceous plants; these utilitarian “roof meadows” generally have no public access and require little maintenance. In contrast, intensive green roofs include shrubs and small trees planted in more than six inches of growing medium; they are often designed as accessible building amenities. This fact sheet focuses on extensive green roofs and their stormwater management benefits. Both types of green roofs seek to transform rooftops from “wasted space” into a form of infrastructure that has environmental, economic, aesthetic, and social benefits.

### Applications and Design Principles

Green roofs are appropriate for commercial, industrial, and residential structures, especially those with a wide roof area. They can be incorporated into new construction or added to existing buildings during renovation or re-roofing. Most green roofs are built on flat or low-angle rooftops, but some have been installed on pitched roofs up to 40% slope, with special design features to prevent slumping and ensure plant survival.

Green roofs are appropriate anywhere it is desirable to reduce the overall amount of stormwater runoff. They are an excellent technique to use in dense urban areas, in areas where infiltration is difficult due to tight soils or shallow bedrock, or on sites where infiltration is undesirable due to existing soil contamination. Because green roofs return rainwater to the atmosphere,

### Management Objectives

- Reduce total runoff volume through rainwater storage and evapotranspiration.
- Reduce peak discharge rates.
- Reduce heating and cooling costs through roof insulation.
- Extend roof life.



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Above, top: The Ford Dearborn Truck Assembly Plant in Dearborn Michigan has a 10-acre green roof that is a 2004 Green Roof Awards of Excellence Winner.  
 Photo: William McDonough + Partners



Above, bottom: The Fencing Academy of Philadelphia was retrofit with a 3.5"-thick green roof, installed over the existing roof structure.  
 Photo: © 2005, Roofscapes, Inc. Used by permission; all rights reserved.

Right: A schematic diagram of a green roof system. Image: City of Portland, OR Environmental Services.

Cover, top: A green roof at the Yorktown Square Condominiums in Falls Church, VA. This installation was a 2005 Green Roof Awards of Excellence Nominee.  
 Photo: Building Logics, Inc.

Cover, bottom: This green roof at the Heinz 57 Center in Pittsburgh is located on the 14th floor and requires no irrigation. It is a 2005 Green Roof Awards of Excellence Nominee.  
 Photo: © 2005, Roofscapes, Inc. Used by permission; all rights reserved.

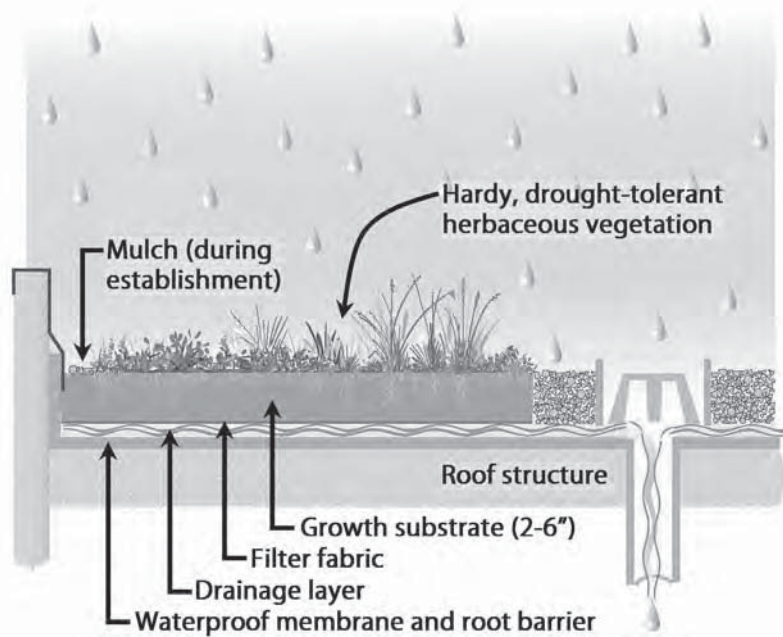
Opposite top: Workers conduct semi-annual maintenance at the Life Expression Wellness Center in Pennsylvania.  
 Photo: © 2005, Roofscapes, Inc. Used by permission; all rights reserved

they should not be used in situations where groundwater recharge is a priority, such as in stressed basins with chronic low-flow conditions. In these circumstances, roof runoff should be infiltrated whenever feasible.

Like conventional roofs, the basic element of a green roof is a waterproof membrane over the roof sheathing. The system also includes a root barrier; a drainage layer; filter fabric; and 2"-6" of a lightweight growth substrate consisting of inorganic absorbent material such as perlite, clay shale, pumice, or crushed terracotta, with no more than 5% organic content. Substrates should not be too rich in organic material such as compost, because of the potential for settling, nutrient export, and too-rapid plant growth. Gravel ballast is sometimes placed along the perimeter of the roof and at air vents and other vertical elements, in order to promote drainage and facilitate access.

Extensive green roofs require moderate structural support which can be easily accommodated during design for new construction; existing roofs may be adequate or may require additional structural supports that can be added during re-roofing or renovation. An extensive green roof may weigh approximately 10-25 pounds per square foot when fully saturated, whereas a conventional rock ballast roof weighs approximately 10-12 pounds per square foot (neither figure includes potential snow load.)

Vegetation on extensive green roofs usually consists of hardy, low-growing, drought-resistant, fire-resistant plants that provide dense cover and are able to withstand heat, cold, and high winds. Varieties commonly used include succulents such as sedum (stonecrop) and delosperma (ice plant.) During dry periods, these plants droop but do not die back; when it rains, they quickly revive and absorb large



amounts of water. Grasses and herbs are less common on green roofs because to survive dry periods they require either irrigation or deeper substrate that retains more water.

A common concern about green roofs is the potential for leaks. The performance of green roofs has improved dramatically since the 1970s, when many leak problems were associated with the first generation of green roofs. Current waterproofing materials, root barriers, and rigorous design and construction standards have largely eliminated these problems; low-cost electronic grids installed under the membrane during construction can also help to pinpoint leaks and minimize repair costs.



Above, middle: A photo of the green roof at the Bruker Deltronics Headquarters in Billerica, MA. Photo: © 2005, Roofscapes, Inc. Used by permission; all rights reserved.

Above, bottom: A close up of low-growing, spreading green roof vegetation. Photo: Building Logics, Inc.

### Benefits and Effectiveness:

- ▣ Green roofs effectively reduce stormwater runoff. Researchers at North Carolina State have found that a 3" green roof can retain approximately 0.6" of rain for each rainfall event, even when storms come on consecutive days. The Center for Green Roof Research at Penn State University reports that a 4" green roof can retain 50% of total rainfall over a series of storm events.
- ▣ Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90% compared to conventional roofs, and peak discharge is delayed by an hour or more.
- ▣ Green roofs lower heating and cooling costs because the trapped air in the underdrain layer and in the root layer help to insulate the roof of the building. During the summer, sunlight drives evaporation and plant growth, instead of heating the roof surface. During the winter, a green roof can reduce heat loss by 25% or more.
- ▣ Because green roofs shield roof membranes from intense heat and direct sunlight, the entire roofing system has a longer lifespan than conventional roofs.
- ▣ The presence of a green roof helps to reduce air temperatures around the building, reducing the "heat island" effect and reducing the production of smog and ozone, which forms in the intense heat (175 degrees) over large conventional roofs. The vegetation on green roofs also consumes carbon dioxide and increases the local levels of oxygen and humidity.
- ▣ Green roofs have demonstrated aesthetic benefits that can increase community acceptance of a high-visibility project; they may also add value to the property if marketed effectively.



Above: Installation of eight inches of soil medium using pneumatic equipment at the Oaklyn Branch Library in Evansville, IN. Photo: © 2005, Roofscapes, Inc. Used by permission; all rights reserved.

### Limitations

- Load restrictions are usually the main limitation for green roofs in retrofit applications. A professional engineer must assess the necessary load reserves and design a roof structure that meets state and local codes.
- Slopes greater than 15% require a wooden lath grid or other retention system to hold substrate in place until plants form a thick vegetation mat.
- Green roofs should not be used where groundwater recharge is a priority, such as in aquifer recharge areas or watersheds experiencing low-flow stresses.
- The initial construction cost is higher than conventional roofs.

### Maintenance

- Green roofs require some support during establishment and then yearly maintenance thereafter. Plants or sprigs should be irrigated until established, and additional plants or sprigs added to ensure good plant coverage if necessary. With drought-resistant vegetation, irrigation of an extensive green roof is rarely necessary after the two-year establishment period.
- Weeding and mulching may be needed during the establishment period and periodically thereafter over the life of the roof. Any woody plants which become established on the roof need to be removed regularly.
- If necessary (many roofs can survive on deposition of airborne nitrogen and biomass breakdown), application of a slow-release fertilizer once a year will ensure continued vigorous growth of the vegetation. Soluble nitrogen fertilizers and compost should not be used due to the potential for nutrient and bacteria export.

### Cost

Green roofs start at \$5 per square foot. They generally cost more to install than conventional roofs, but are financially competitive on a life-cycle basis because of longer life spans (up to 40 years), increased energy efficiency, and reduced stormwater runoff. If the application is a retrofit, structural upgrades may increase the cost somewhat.

### Design Details:

- Waterproof membranes are made of various materials, such as modified asphalts (bitumens), synthetic rubber (EPDM), hypolan (CPSE), and reinforced PVC. The most common design used in Europe is 60-80 mil PVC single-ply roof systems. Modified asphalts usually require a root barrier, while EPDM and reinforced PVC generally do not. Attention to seams is critical because some glues and cements are not always root impermeable.
- The underdrain layer may be constructed of perforated plastic sheets or a thin layer of gravel. Pitched roofs and small flat roofs may not require an underdrain.
- Vegetation should be low-growing, spreading perennial or self-sowing annuals that are drought tolerant. Appropriate varieties include sedum, delospermum, sempervivium, creeping thyme, allium, phloxes, anntenaria, ameria, and abretia. Vegetation may be planted as vegetation mats, plugs or potted plants, sprigs (cuttings), or seeds. Vegetation mats are the most expensive but achieve immediate full coverage. Potted plants are also expensive and labor intensive to install. Sprigs are often the most cost effective option, even considering that initial irrigation is necessary and repeat installations may be required due to mortality. Conventional sod should not be used because it requires irrigation, mowing, and maintenance.
- Access routes should be identified during the design phase, and access paths of gravel or other inert materials provided, as well as safety harness hooks for inspection and maintenance personnel.

### For more information

[www.greenroofs.org](http://www.greenroofs.org) (Green roof industry association; training and design courses)  
[www.greenroofs.com](http://www.greenroofs.com)  
 (The Green Roof Industry Resource Portal)  
[www.bae.ncsu.edu/greenroofs/](http://www.bae.ncsu.edu/greenroofs/)  
 (North Carolina State University)  
[hortweb.cas.psu.edu/research/greenroofcenter/](http://hortweb.cas.psu.edu/research/greenroofcenter/)  
 (Penn State University)  
[www.greeninggotham.org/home.php](http://www.greeninggotham.org/home.php)  
[www.roofmeadow.com](http://www.roofmeadow.com)  
 (North American Green Roof Provider)

*This publication is one component of the Massachusetts Low Impact Development Toolkit, a production of the Metropolitan Area Planning Council, in coordination with the I-495 MetroWest Corridor Partnership, with financial support from US EPA. The Massachusetts Low Impact Development Interagency Working Group also provided valuable input and feedback on the LID Toolkit.*

**FOR MORE INFORMATION, VISIT: [WWW.MAPC.ORG/LID](http://WWW.MAPC.ORG/LID) AND [WWW.ARC-OF-INNOVATION.ORG](http://WWW.ARC-OF-INNOVATION.ORG).**