

Green (or Vegetated) Roofs



Vegetated Roof in Norway
(Source: Wikimedia)

Purpose & Benefits

- Reduce runoff from rooftops
- Lower utility bills
- Better roof longevity
- Aesthetic amenity

Description

Green Roofs (also known as Vegetated Roofs) capture and temporarily store stormwater runoff before it flows into the roof guttering system. Components of a Green Roof include low-growing, drought-tolerant plants (such as sedum species), an engineered growing medium that is designed to support plant growth, and an alternative roof surface that typically consists of waterproofing and drainage materials. Water drains vertically through the media and then horizontally along a waterproofing layer towards the roof drains/gutters. The Green Roof performs several critical stormwater runoff related functions; filters pollutants from the air and rain water, and reduces volume, force of flow, and water temperature.

What to Expect

The materials of a Green Roof are heavier than a typical roof, so buildings must meet certain structural standards in order to support the extra weight. Consult a building engineer or architect to determine if the structure will adequately handle the load. Some irrigation is likely necessary after installation to ensure the plants get established, but plant species are selected so that the roof does not need supplemental irrigation or fertilization after vegetation is initially established. Removing invasive plants, weeding, and overall vegetation management are the primary maintenance considerations, as well as structural repairs as needed.

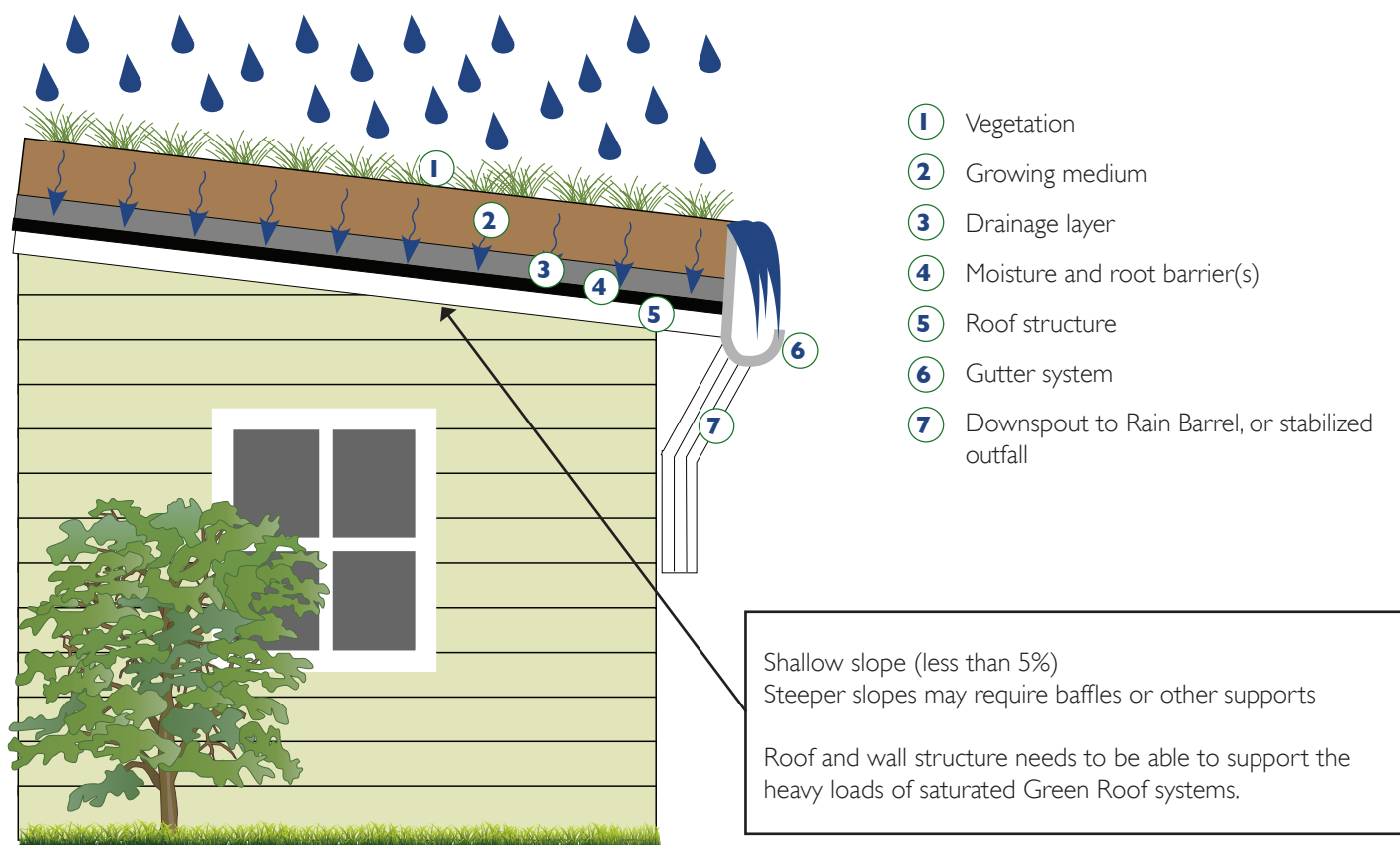


Figure 6.1. *The components of a typical Green Roof*

6.1. Complexity

A Green Roof is likely not something that can be installed by someone without some building experience. Green Roof systems contain multiple components and have many design considerations that are generally outside the expertise of those who do not design and build structures. Therefore, this practice will likely require at least a licensed contractor; and possibly an engineer or architect, to properly design and build (see guidance in **Table 6.1**).

“Extensive” Green Roofs typically have 2 to 8 inches of growing media, whereas “intensive” Green Roofs have thicker media that can capture and treat more water and support the growth of larger plants (e.g., shrubs and trees). Some homeowners and landscape contractors install basic extensive Green Roof systems themselves with good success, but typically these are installed on accessory buildings.

Understand the Complexity of the Green Roof Project

The intent of this guide is for practices in the **SIMPLE** or low end of **MODERATE** categories, and for modular and/or extensive systems. Even if the practice is in the simple category, consider consulting with an appropriate design professional, as Green Roofs must be integrated with the existing structure and involve inherent complications.

Green Roofs should be designed and constructed by a contractor with experience and knowledge about this practice. The design and construction details provided in this chapter may allow Stewards and homeowners to better understand the practice, but not to construct this practice without the help of an experienced contractor.



Table 6.1. Design Complexity for Green Roofs

Design Complexity	Description	Guidance
Simple	<ul style="list-style-type: none"> • Basic construction, fewer layers or components • Some kits available for homeowners with sturdy, shallow-sloped roofs • Sheds, garages, possibly main residence 	<ul style="list-style-type: none"> • Waterproofing is important, especially if on a residence or other enclosed building • Structure must be strong and roof slope should be shallow, usually <3% • Techniques for steeper roofs are available, such as using a tray matrix, baffles or grids.
Moderate	<ul style="list-style-type: none"> • Extensive Green Roofs, shallower commercial systems or traditional designs • Special materials for waterproofing and root barrier should be used • Can weigh more than 50 pounds/square foot when saturated • Steeper slopes possible, but special installation is required 	<ul style="list-style-type: none"> • Design should be provided by a professional, such as an architect, engineer, or Green Roof design/ installation professional • Design should be made using accepted construction specifications • Construction will likely require specialized contractor
Complex	<ul style="list-style-type: none"> • Intensive Green Roofs, deeper, more comprehensive systems • Can handle fairly large rain events • Can weigh more than 100 pounds/ square foot when saturated • Most likely only for commercial, institutional, or industrial buildings due to load-bearing requirements • Very expensive 	<ul style="list-style-type: none"> • Requires a professional architect or engineer in addition to Green Roof specialist • Requires adherence to state or local stormwater or Green Roof manual design specifications • May require more maintenance than other Green Roof systems

6.2. Location & Feasibility

When deciding whether a Green Roof is an appropriate practice for a specific property, it is important to consider the following:

Structural Capacity of the Roof When designing a Green Roof, designers must not only consider the water storage capacity of the Green Roof, but also its structural capacity to support the weight of the additional water. An existing conventional rooftop typically must be modified to support an additional 15 to 30 pounds per square foot for an extensive Green Roof. As a result, a structural

Understand the Constraints

The roof and structure must be strong enough to hold the weight of the saturated Green Roof, plus the necessary other loads like snow and wind typical for the region.



Do:

- Consult a structural engineer or architect to verify that building can carry the weight of Green Roof
- Plan access to roof for construction and for long-term maintenance
- Look up local building codes and state design specifications for Green Roofs

Don't:

- Attempt to install Green Roof on slopes steeper than 25%

up to the roof. Also, have a plan for staging construction materials on the roof. Regular maintenance may be required depending on a number of factors, which will necessitate accessing the roof and possibly carrying some replacement materials up to and around the roof.

Roof Type Green Roofs can be applied to most roof surfaces, although concrete roof decks are preferred. Certain roof materials, such as exposed treated wood and uncoated galvanized metal, may not be appropriate for Green Roofs due to pollutants leaching through the media.

Local Building Codes Consult local permitting authorities to obtain proper permits. In addition, the Green Roof design should comply with local building codes with respect to roof drains and emergency overflow devices.

6.3. Design

With the caveat that any Green Roof design should at least be examined and confirmed by an experienced design professional, the design elements are listed below. Material specifications for Green Roofs vary based on each roofing system. Obtain specific information from the appropriate roofing system manufacturer or retailer. The following information and specifications, which include acceptable materials for generic applications, are not exclusive or limiting. If the specifications below are too complex for the proposed application, use a pre-engineered kit suitable for the structure or consult with a Green Roof professional. The following material and media specifications are from the Green Roof section of the *Maryland Stormwater Design Manual*, Appendix B.4.A.

engineer, architect, or other qualified professional should be recruited to verify that the building has enough structural capacity to support a Green Roof. An intensive Green Roof is deeper and can have much heavier loads.

Roof Pitch Green Roof stormwater storage volume is maximized on relatively flat roofs (a slope of 1 to 2%). However, enough slope is needed to ensure good drainage and prevent ponding on top of the growing media. Green Roofs can be installed on rooftops with slopes up to 25% if baffles, grids, or strips are used to prevent slippage of the media. Most residential roofs are too steep for a Green Roof system that does not have baffles or other slip-stops.

Roof Access Adequate access to the roof must be available to deliver construction materials and perform routine maintenance. Consider if a forklift, crane, or other equipment is needed to get construction materials



Figure 6.2. *Vegetated Roof on a home in Maryland.*

(Source: Chesapeake Conservation Landscaping Council)



Green Roof layer, from bottom to top:

Deck Layer The roof deck layer is the foundation of a Vegetated Roof. It may be composed of concrete, wood, metal, plastic, gypsum or a composite material. The type of deck material determines the strength, load-bearing capacity, longevity, and potential need for insulation in the Green Roof system.

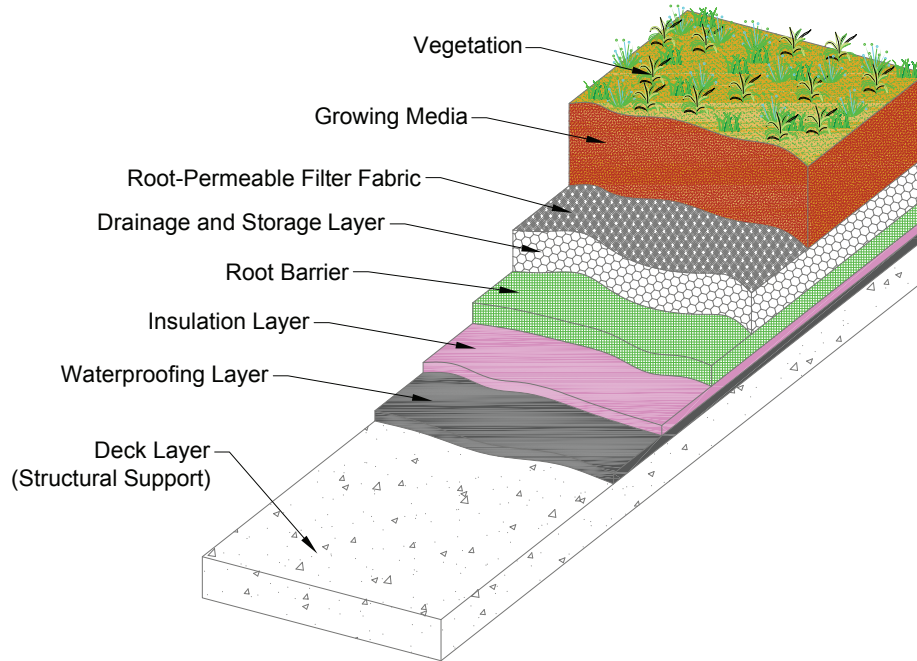


Figure 6.3. *Typical layers of a Green Roof*

Waterproofing Layer All Green Roof systems must include an effective and reliable waterproofing layer to prevent water damage through the deck layer. The waterproofing layer must be completely waterproof and have an expected life span as long as any other element of the Green Roof system, and ideally the roof itself.

Insulation Layer Many Vegetated Rooftops contain an insulation layer, usually located above, but sometimes below, the waterproofing layer. The insulation increases the energy efficiency of the building and/or protects the roof deck (particularly for metal roofs).

Root Barrier The next layer of a Vegetated Roof system is a root barrier that protects the waterproofing membrane from root penetration. Avoid chemical root barriers or physical root barriers that have been impregnated with pesticides, metals, or other chemicals that could leach into stormwater. Root barriers should be thermoplastic membranes with minimum thickness of 30 mils (0.030 inches).

Waterproofing Layer

It is vital that the waterproofing layer is both installed correctly, and suitably designed for the application. Subsequent installation and maintenance work must be performed carefully so as not to damage the waterproofing layer. If the waterproofing layer fails, serious damage can occur to the structure below.



Drainage Layer and Drainage System A drainage layer is placed between the root barrier and the growing media to quickly remove excess water from the vegetation root zone. The drainage layer should consist of synthetic or inorganic materials, such as gravel or recycled polyethylene, that are capable of providing fast drainage (see **Table 6.2** for specifications). The required depth of the drainage layer is governed by both the desired stormwater storage capacity and the structural capacity of the rooftop.

Table 6.2. Granular Drainage Media

(From MDE, 2000 p. B.4.2)

Saturated hydraulic conductivity	≥ 25 inches/minute
Total organic matter (by wet combustion)	≤ 1%
Abrasion resistance (ASTM C131-96)	≤ 25% loss
Soundness (ASTM C88 or T103 or T103-91)	≤ 5% loss
Porosity (ASTM C29)	≥ 25%
Alkalinity, CaCO ₃ equivalents (MSA)	≤ 1%
Grain Size Distribution	
% Passing # 18 sieve	≤ 1%
% Passing 1/8 inch sieve	≤ 30%
% Passing 3/8 inch sieve	≤ 80%

Root-Permeable Filter Fabric Semi-permeable polypropylene filter fabric is normally placed between the drainage layer and the growing media to prevent the growing media from migrating into the drainage layer and clogging it (**Table 6.3**).

Table 6.3. Root-Permeable Filter Fabric - non-woven geotextile

(From MDE, 2000 p. B.4.2)

Unit weight (ASTM D3776)	≤ 4.25 oz. per square yard
Grab tensile strength (ASTM D4632)	≤ 90 pounds
Mullen burst strength (ASTM D4632)	≥ 135 pounds/inch
Permittivity (ASTM D4491)	≥ 2 sec ⁻¹

Growing Media The next layer in an extensive Green Roof is the growing media, which is typically 2 to 8 inches deep. As the name suggests, this is the layer in which the plants grow. This can be soil or alternative materials designed to sustain plant growth. **Tables 6.4 and 6.5** provide typical specifications for the growing media.



Table 6.4. Growing Media

(From MDE, 2000 p. B.4.1)

Non-capillary pore space at field capacity, 0.333 bar (TMECC 03.01, A)	≥ 15% (volume)
Moisture content at field capacity (TMECC 03.01, A)	≥ 12% (volume)
Maximum media water retention (FLL)	≥ 30% (volume)
Alkalinity, CaCO ₃ equivalents (MSA)	≤ 2.5%
Total organic matter by wet combustion (MSA)	≤ 3-15% (dry weight)
pH (RCSTP)	6.8-8.0
Soluble salts (DTPA saturated media extraction - RCSTP)	≤ 6 mmhos/cm
Cation exchange capacity (MSA)	≥ 10 meq/100 g
Saturated Hydraulic Capacity (MSA)	
>Single media assemblies	≥ 0.05 inches/minute
>Dual media assemblies	≥ 0.30 inches/minute

Table 6.5. Mineral Fraction Grain Size Distribution (ASTM D422)

(From MDE, 2000 p. B.4.1)

	Single Media	Dual Media
Clay fraction	0	0
% Passing #200 sieve	≤ 5%	5-15%
% Passing #60 sieve	≤ 10%	10-25%
% Passing #18 sieve	5-10%	20-50%
% Passing 1/8 inch sieve	20-70%	55-90%
% Passing 3/8 inch sieve	75%-100%	90-100%

Plant Cover The top layer of a Green Roof consists of slow-growing, shallow-rooted, perennial, succulent plants that can withstand harsh conditions at the roof surface. A mix of base ground covers (usually Sedum species) and accent plants can be used to enhance the visual appeal. Intensive Green Roofs with deeper growing media can have a variety of shrubs, small trees, and ground cover.



6.4. Materials

Materials will vary based on the type of Green Roof system and design and the particular manufacturer's specifications. **Table 6.6** is a less specific list of materials with approximate quantities in ranges relative to the roof area. General descriptions and specifications are above in the design section.

Table 6.6. Materials List

Material Item	Required or Optional	Comments/Notes	Approximate Quantity
Deck layer	Required	Optional only if roof already has an acceptable base material	Roof area
Waterproofing layer	Required		Roof area
Insulation layer	Optional		Roof area
Root barrier	Required	<i>If</i> waterproofing layer is absolutely impermeable to root penetration, this is optional (not likely)	Roof area
Drainage layer	Required		Depends on how much storage is designed and the structural capacity of the roof <i>Per inch</i> of layer depth: (Roof area)/12
Root-permeable filter fabric	Required	Optional only if the growing media used is not loose, and cannot clog the drainage layer beneath	Roof area
Growing media	Required		Quantity can vary greatly <i>Per inch</i> of layer depth: (Roof area)/12 Probable range: (Roof area)/6 to (Roof area)/2
Plant cover	Required	Coverage area is the whole Green Roof, but the plant selection drives quantity of plants or seeds Consultation with a Green Roof specialist, specialty nursery, or design professional may be needed	Roof area



6.5. Construction

Given the diversity of extensive Green Roof designs, there is no typical step-by-step construction sequence for proper installation. The following general construction considerations are noted:

Step 1 – Roof Deck Construct the roof deck with the appropriate slope and material, or ensure that the existing roof deck material can support and is adequate for a Green Roof.

Step 2 – Install Waterproofing Install the waterproofing method according to manufacturer's specifications.

Step 3 – Test the Waterproofing Conduct a flood test to ensure the system is watertight.

Step 4 – Install Other Layers Add additional system components (e.g., insulation, root barrier, drainage layer and interior drainage system, and filter fabric), taking care not to damage the waterproofing. Drain collars and protective flashing should be installed to ensure free flow of excess stormwater.

Step 5 – Add Growing Media Mix the growing media prior to delivery to the site. Spread media evenly over the filter fabric surface. Cover the growing media until planting to prevent weeds from growing. Sheets of exterior grade plywood can also be laid over the growing media to accommodate foot or wheelbarrow traffic. Limit foot traffic and equipment traffic over the growing media to reduce compaction.

Step 6 – Add Plants Moisten the growing media and plant with ground cover and other plant materials, as per the plan. Water plants immediately after installation and routinely during establishment.

Step 7 – Fertilize & Water Fertilize using slow release fertilizer (e.g., 14-14-14) with adequate minerals to support growth, if specified by the media manufacturer. Temporary watering may also be needed during the first summer, if dry conditions persist.

Do:

- Follow specific instructions of Green Roof material manufacturers
- Plan out how to maneuver around roof during installation
- Fertilize and water as needed to get the plants established

Don't:

- Damage waterproofing layer during installation of other layers – it is crucial!



6.6. Maintenance

Access

It is important to think about access to and from the roof when considering whether to install a Green Roof. Maintenance requires getting onto and safely moving about the roof, most likely with some materials and tools.

Table 6.7. Recommended Maintenance for Green Roofs

Activity	Schedule
<ul style="list-style-type: none"> Water to promote plant growth and survival Inspect the roof and replace any dead or dying vegetation 	As needed (following construction)
<ul style="list-style-type: none"> Inspect the waterproof membrane for leaks or cracks and repair as needed Weed to remove invasive plants (no digging or using pointed tools) Inspect roof drains, scuppers, and gutters to ensure they are not overgrown or have organic matter deposits and remove any accumulated organic matter or debris Inspect the roof for dead, dying, or invasive vegetation and plant replacement vegetation as needed 	Semi-Annually
<ul style="list-style-type: none"> Fertilize (first 5 years) 	Annually

6.7. Resources

Green Roof Directory

<http://www.greenroofs.com/resources.htm>

Hirschman, D., & Collins, K. (2008). Technical Memorandum : *The Runoff Reduction Method*.

Maryland Department of the Environment. (2000). Maryland Stormwater Design Manual. Vol. 2. Appendix B.4.A Green Roof Specifications.

Virginia Department of Environmental Quality. 2013. *Virginia Stormwater BMP Specifications – Rev. 2013 (DRAFT)*. Available at: <http://www.deq.virginia.gov/Programs/Water/StormwaterManagement/Publications.aspx>