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Vegetated Green Roofs in Germany and the U.S.

by Molly Meyer, M.Sc., GRP, ASLA, LEED Green Associate

Learning Objectives:
After taking this course, the reader will:
1. Know the definition and benefits of green roofs
2. Understand green roof design types and installation methods
3. Learn the history of green roofing in Germany
4. Understand how the U.S. can learn from the German green roofing experience

Vegetated Green Roofs and their Benefits

A vegetated green roof, also called a vegetated roof, green roof, garden roof, eco roof, or planted roof, among other terms, is a system above a waterproofed structure that supports the long-term growth of plants. Although this is a broad definition of a green roof, there are two critical points. First, a vegetated green roof is a system above a waterproof structure. Primarily, a green roof is a roof. No matter how pretty the plants are, if the building underneath them gets wet or collapses, then a green roof has failed as a roof. Therefore, the structure has to be strong enough to hold the weight of the vegetation system, and the roofing membrane must be waterproof. Second, a vegetated green roof needs to support the long-term growth of plants. The growing media, drainage system, and other components of the green roof must create a long-lasting, lush green space on a rooftop.

Green roofs benefit both the environment and building owners and occupants. The environmental benefits include:

- **Reduction of the urban heat island effect.** The urban heat island effect is a phenomenon that occurs in cities in which the air temperature in dense urban centers is several degrees higher than the outlying suburban and rural areas' air temperatures. The urban heat island effect is a result of many surfaces, like roads, sidewalks, and blacktop roofs, absorbing and radiating heat. Plants naturally cool the surrounding air through transpiration, which is the process by which plants lose water and convert carbon dioxide into oxygen. When buildings and surfaces are covered with greenery, this natural cooling process is employed to lower the ambient air temperature relative to the temperature near unplanted surfaces on a hot day.
- **Improvement of urban air quality.** Vegetation pulls industrial dust and soot out of the air, consumes carbon dioxide, and creates oxygen.
- **Decrease in noise pollution.** When there are many hard surfaces, like concrete and brick, noises bounce off those surfaces and create a loud place to live and work. Covering surfaces with plants dampens sounds.
- **Increase in biological diversity and connection of species habitats.** Green roofs create a stopping point for migratory species like birds and butterflies. A series of green roofs in a city can create a corridor of habitats, giving species safe harbor and improving their chances of survival.

Green roofs also create numerous benefits to building owners and users. These benefits include:

- **Increase in the lifetime of roofing membranes.** Roofing membranes degrade over time due to exposure to extreme temperatures and ultraviolet radiation. Green roofs prevent UV rays from hitting the underlying membranes and limit temperature fluctuations. This helps roofing membranes last longer. Green roofs can remain on the same roofing membrane for up to 50 years or more.
- **Decrease in building energy use.** Studies have shown that air conditioning loads can be decreased as much as 25 percent when a green roof is added to a building. A vegetated roof's surface temperature is at most 90 degrees on a hot summer day. The surface temperature of a black rooftop can reach 150 degrees or more on the same day, so the HVAC system has to use more energy to cool the 150-degree exterior surface temperature to a 70-degree interior air temperature than it would if the building had a green roof. The exact energy savings is different for each roof and each season and depends on many factors including the local climate, the proportion of roof area to total surface area of a building, and the location of the HVAC system air intake.
- **Mitigation of stormwater runoff.** Green roofs act as sponges: absorbing water during rain events and slowly releasing it later on. This decreases the volume spikes in cities' stormwater runoff systems and prevents combined stormwater overflow. When civil engineers include the stormwater mitigation effects of green roofs in their design calculations, they can often decrease the size of a project's stormwater retention tank and save the owner money. In some municipalities, buildings with green roofs offer property owners stormwater tax reductions.
- **Increase in usable outdoor space.** Green roofs create a pleasing natural environment, which can be used as entertainment spaces, meditative areas, vegetable gardens, and children's play spaces.

Design Types and Installation Methods of Green Roofs

Green roofs come in many different forms. They are classified by design types and by installation methods. There are three different design options for green roofs: extensive

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roofs, intensive roofs, and semi-intensive roofs. There are two different installation options for green roofs: modular systems and built-in-place systems.

Design types:

- Extensive roofs have a total system depth of less than six inches, low saturated weight (10-35 lbs/sf), low cost per square foot, and minimal maintenance requirements. They are typically inaccessible, other than for maintenance personnel. Plant diversity is low because plant selection is often limited to sedum (pronounced SEE-dum). Sedum are robust, drought-tolerant plants. [Figure 1.]

Figure 1

- Intensive roofs have a total system depth of more than six inches, high saturated weight (35-100 lbs/sf or more), high cost per square foot, and high maintenance requirements. Intensive roofs are maintained with equal or greater care as traditional manicured green spaces on the ground. They are usually accessible to building occupants, offering additional usable outdoor space in the form of manicured lawns and gardens, vegetable gardens, meditative spaces, and play areas. Plant diversity is high because a landscape architect, landscape designer or garden enthusiast selects plants and develops a planting plan. [Figure 2.]

Figure 2

- Semi-intensive roofs have a total system depth between five and seven inches, moderate saturated weight (35-50 lbs/sf), mid-range cost per square foot, and moderate maintenance requirements. Access is generally limited to maintenance personnel. Semi-intensive roofs are designed for greater plant diversity and greater stormwater retention than extensive roofs. They are often designed to provide a native plant environment or a plant and animal refuge. They are generally not designed with a manicured layout and strict planting plan, which are typical of intensive roofs. [Figure 3.]

Figure 3

Installation methods:

- A modular system is a series of trays that are installed like tiles, one next to the other, until the roof is covered to create a grid of greenery across a roof surface. Tray sizes vary but are most commonly one foot by two feet or two feet by four feet. Trays are often black molded plastic, although there are aluminum and biodegradable versions available. The trays include an internal drainage system and are filled with growing media and planted before they are delivered to the roof. Modular systems are available in system depths between two and six inches, so they can be used for extensive green roofs and some semi-intensive roofs but are not appropriate for intensive roofs. Modular systems, depending on the supplier, can be used on sloped roofs up to 4:12 pitch. [Figure 4.]

Figure 4

- A built-in-place system is a green roof that is installed one layer at a time, like a sandwich, rather than like tiles as with a modular system. The components of a built-in-place system vary based on design goals but often include from water-proof structure to planted surface: a protection fabric over the roofing membrane and root barrier, a drainage layer, a filter fabric, growing media, and plants. Built-in-place systems can be designed to meet any green roof goal, including extensive, semi-intensive, and intensive roofs. Built-in-place systems are available for sloped roofs up to 10:12 pitch and can be custom-engineered for steeper roofs. [Figure 5.] [Figure 6.]

Figure 5

Design Type	Modular	Built-in-place
Extensive	Yes	Yes
Intensive	No	Yes
Semi-intensive	≤ 6" deep	Yes
Sloped	≤ 4:12 pitch	≤ 10:12 pitch

Figure 6

There are advantages and trade-offs to each green roof installation method. When selecting a system for a project, it is important to consider the following factors: design goals, budget, roof area, and roof access. Both modular and built-in-place systems are appropriate for extensive and semi-intensive roofs. However, only built-in-place systems can be used for intensive roofs and sloped roofs greater than 4:12 pitch.

Both modular and built-in-place systems can be instantly "green", that is have more than 80 percent plant coverage on the day of installation. "Fully-green" modular systems must be grown in a nursery for three to four months before the day of installation, and "fully-green" built-in-place systems must be planted with a vegetated sedum mat, which looks much like a roll of sod.

Material costs per square foot for modular systems are higher than for built-in-place systems. In spite of their higher material costs, modular systems can sometimes save on labor expenses, since modular systems are easier to install on small roof areas and on roofs with difficult access. For instance, if necessary, trays could be delivered to a roof by hand with many trips up and down the stairs! Though built-in-place systems' materials are less expensive per square foot, each layer is installed individually and supplied in bulk, so there must be space for a crane near the building. Significant surplus can remain from materials supplied in bulk. For example, the smallest roll sizes for filter fabric varies based on supplier from 500 to 4500 square feet.

Both the on-going maintenance and the potential removal of green roof materials in the case of a leak in the underlying membrane (called "overburden removal") are often cited as reasons to choose modular or built-in-place systems. But, there is little evidence to support a difference between the systems' performances in these areas. The amount of maintenance required for a green roof is a function of the planting method used. When an extensive green roof is planted with plugs or cuttings, weeds can compete with the young plants for space, water and nutrients in the largely-uncovered growing media. However, when an extensive roof is planted with either fully-grown trays or vegetated sedum mats, weeds do not have the opportunity to grow in the already-covered growing media.

Overburden removal is an enormous task regardless of how the green roof is installed. Both green roof systems cover the roofing membrane, greatly hampering efforts to "chase a leak" if a breach in the membrane is discovered after green roof installation. The best ways to prepare for the unfortunate task of overburden removal are to (1) employ a construction management plan after the membrane has been leak tested, (2) use experienced and conscientious contractors for roofing work and trades after roofing, and (3) install an electronic field vector map (EFVM). EFVM is a series of wires, which are laid on or imbedded within the roofing membrane to detect a membrane breach within inches. EFVM must be installed at the time of membrane installation, before the green roof is placed. Then, it is permanently available to identify leaks so that only a small section of green roof materials would be displaced for roofing repairs. [Figure 7.]

Factor	Modular	Built-in-place
Extensive	Yes	Yes
Design options	Limited	Unlimited
Instant green	Yes	Yes
Material cost	High /sf	Low /sf
Roof area	Small	Large
Roof access	Unlimited	Limited
Maintenance	n/a	n/a
Removal	n/a	n/a

Figure 7

Development of Green Roofing in Germany

In green roof discussions, Germany is bound to come up. Green roofing has been a part of modern building practices in Germany for since the 1980s. One hundred and forty million square feet of green roof area are installed annually in Germany. In North America, 3.2 million square feet is the most green roof area installed in one year. Understanding the historical development of the German green roof market is important because green roof designers, installers, maintenance personnel, and building owners in the United States can learn from the successes and failures that have already been achieved through the experience of German green roofers.

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As early as the 1800s, unintentional green roofs were a part of the building code in Berlin and other German cities. The Berlin building code of the time required standard roofing systems to include tongue-and-groove decking and tar-paper membrane. The membranes were covered with two centimeters of sand and eight centimeters of gravel. The intended result of the covering was to protect the underlying membrane from temperature extremes and to avoid heavy maintenance burden of repairs. Unintentionally, these roofs spontaneously vegetated.

Some of these 19th Century green roofs still exist today, although most were destroyed during the First and Second World Wars. During Germany's reconstruction after WWII, modern roofing membranes were used instead of the 19th Century tar-paper systems, so no more spontaneously-vegetating green roofs were built. Additionally, there was little attention paid to including green space and plants in the city. The housing demands were so great that city planners and developers neglected to include green spaces.

By the 1970s, there was a backlash against the loss of connection to nature in cities since post-WWII reconstruction, and a strong environmental movement began in Germany. The increase in awareness of environmental issues inspired a re-thinking of the building practices since WWII. Experiments in new green building technologies, including green roofing, started during this time.

By 1984, the federal government passed legislation that prohibited the unification of water and sewage fees. This meant that property owners had to pay for the water that flowed from their land as well as the water that they used, and it set the groundwork for government-regulated incentives for green roofs in the future.

In the 1980s, large-scale green roof projects and green roof experiments were undertaken. These were organized to (1) measure the environmental benefits of green roofs and (2) identify the critical factors in ensuring long-term plant and roof performance. Berlin city Block 103 was one such experimental project. Local residents took over the condemned buildings on Block 103 from the city and renovated them with green roofs, among other environmental measures including solar panels and geothermal wells. In total, more than 13,000 square feet of green roofs were installed on six buildings in Block 103.

From experiments and projects like Block 103 in Berlin, the Forschungsgesellschaft Landschaftsentwicklung Landscaftsbau, e.V. (FLL), in English "Landscape Development and Construction Research Association," developed a set of standards for building long-lasting green roofs. FLL first published a set of basic principles for green roofing in 1982. In 1990, FLL published the first green roofing guidelines, accepted as industry best practices and informed by the results of experiments in the 1980s. These guidelines are called "Richtlinie für die Planung, Ausführung und Pflege von Dachbegrüngen," in English "Guidelines for the Planning, Execution, and Upkeep of Green Roof Sites".

Based on the FLL green roof guidelines, city governments were able to include green roof performance data in their stormwater policies. Since 1984, when the federal regulation prohibited the unification of water and sewage fees, property owners were paying taxes for the water they used and for the water that flowed from their land. Green roofs measurably mitigate storm water runoff, and once researchers quantified the amount of mitigation, those values were included in government policies to incentivize, subsidize, or require green roofs. By 1997, 42 percent of German cities had green roof policies. By 2008, 85 percent of German cities had green roof policies.

Green roofing evolved from an unintentional by-product of the standard roofing practices in the 1800s to a novel concept for modern buildings in the 1970s to a meaningful tool for stormwater management for individual property owners and entire cities in the 1990s. As green roofs gained traction in stormwater policies in the 1990s, the green roof market grew. By the 2000s, German green roof suppliers standardized systems and products, provided training programs for professional installers, based their systems and processes on the FLL standards, and offered standard warranties. Today, at some German construction companies, crews of 20 employees work full time on green roof installations and maintenance. The German green roof market is now a well-established, mature industry.

Lessons from the German Green Roofing Experience

As relative newcomers to green roofing technology, green roofers in the United States can learn a great deal from the green roofing experience in Germany. First, German green roofing costs are much lower than costs for similar systems in the U.S., and adopting techniques from German green roofing can save costs for U.S. green roofers. Second, German green roofers have had green roof failures. U.S. green roofers can learn from those examples to avoid repeating costly mistakes.

Green roof material costs and average green roof installed price in Germany are less than in the U.S. Materials for an extensive green roof in Germany can be purchased for as little as $1.75 per square foot, whereas materials for a similar system in the U.S. are $4.50 per square foot. Average installed price for a basic extensive green roof in Germany is $2.80 per square foot, compared to $11 per square foot in the U.S.

Several trends contribute to these cost differences. As mentioned earlier in this article, modular systems are more expensive than built-in-place systems. Modular systems were developed in Germany in the early 1990s. However, after one to two years in the market, they were phased out because they were too expensive. U.S. green roofers are using modular systems because they are standardized and simple to install, even though they are more expensive. As the U.S. green roof market evolves from green roofs as a novelty to a commodity, the market share of modular and built-in-place systems may change.

Aluminum edging is an expensive garden edge detail that is almost ubiquitously specified on U.S. projects. On extensive green roofs in Germany, either a thin, low-cost perforated aluminum edge is used, or instead of garden edging, the filter fabric is flipped up to separate growing media from gravel edges. This German technique reduces material and labor costs.

Planting method also affects average costs. When roofs are planted using plugs and cuttings, they are less expensive to install than planting with vegetated sedum mats. Vegetated mats are used sparingly in German green roofs, whereas they are more commonly found on green roofs in the U.S.

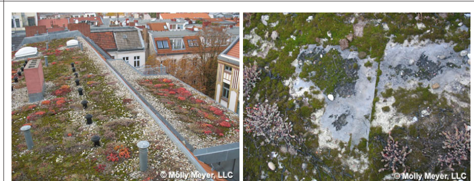
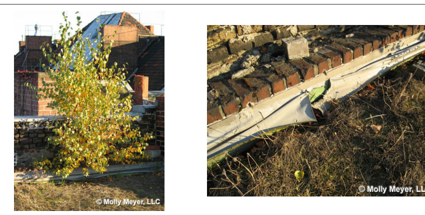
The distribution method of growing media also affects costs. In Germany, specialized blower trucks are used to blow growing media from a semi-truck on the ground through tubing onto the roof surface. This allows for rapid distribution of material across large surfaces. In the U.S. these specialized trucks are not available, so installers use supersacks, which are bags containing two cubic yards of growing media that can be suspended from a crane. Installers handle growing media three times when distributing media from supersacks because they first unload the supersacks from the delivery truck, then hoist the supersacks with a crane, and then pour growing media from the supersacks into wheelbarrows to distribute it across the roof surface. The U.S. method of growing media distribution with supersacks greatly increases labor and material costs associated with installation.

Systemic differences in the construction industry also influence overall costs. Germany is a small country compared to the U.S. With a land area about the size of Montana, distribution networks and blower truck dispatch can be efficiently managed. Many German contractors have access to cranes. Since German contractors are regularly working on tight job sites, cranes are easier to source and cheaper to use in Germany than in the U.S. Employee turnover is lower in Germany than in the U.S., so training costs are lower. Finally, there is no novelty factor for green roofers in Germany, where green roofing is equal to other trades. In the U.S., most green roofs are a new experience for the general contractor, roofer, and landscaper. Therefore, there are inefficiencies and a perception of greater risk.

American preferences also contribute to higher costs in the U.S. Building owners in the U.S. tend to want instantly "green" roofs, with either the simplicity of an extensive modular system or the complexity of an intensive manicured garden. Germans, on the other hand, are satisfied with more natural-looking green roofs with meadow-like appearances and lower installation and maintenance costs. These habits of taste may never change. That said, as more green roofs are built in the U.S., a greater volume of material will be sold and understanding of the technology will spread. Ultimately, volume sales and competition will reduce costs.

Beyond costs, U.S. green roofers can learn from German green roofers' mistakes. Figure 8 shows pictures of green roof failures and lists the problems and the possible solutions. These failed green roofs can be discouraging reminders of expensive mistakes. However, from these lessons and decades of experience, German green roofers have demonstrated how to make beautiful green roofs the rule rather than the exception, through commitment to thoughtful design, careful installation, and on-going maintenance. [Figure 8.]

Figure 8

Failure & Solution	Example
Failure: Too little water **Evidence:** Plants are sparse and reddish in color, which indicates stress. Growing media is thin and low in organics. Drainage layer is dimpled foam board with no water-holding capacity. **Solution:** (1) Use drainage layer with some water-holding capacity; (2) install more growing media; (3) select growing media with more organic content; and (4) consider irrigation system. Caution: too much water can also cause failure.	
Failure: Water erosion **Evidence:** There are patches bare of plants and growing media, patterns of water flow downslope, and thin plant coverage. **Solution:** (1) Install growing media retention system to hold media onto slope; and (2) install more growing media to provide plants with deeper rooting zone.	
Failure: Wind erosion **Evidence:** There is no growing media on the roof. Moss, rather than sedum, is growing, using the filter fabric as a substrate. **Solution:** (1) Use FLL-tested growing media; (2) analyze site's wind exposure before design; and (3) plant using a vegetated mat or cover plants with an erosion-prevention blanket during establishment period.	
Failure: Unwanted plant growth **Evidence:** A tree is growing out of the parapet on the green roof. The caretaker probably caused the flashing damage when carelessly pulling weeds with substantial root growth. **Solution:** Follow a regular maintenance plan, approved by the supplier and designer, with a minimum of semi-annual inspections.	

This is not a comprehensive list. Membrane and structural failures are among possible failures not shown.

Molly Meyer, M.Sc., GRP, ASLA, LEED Green Associate, owns and manages three companies: Molly Meyer, LLC, Rooftop Green Works, LLC, and EcoKnowledge Nexus, LLC. Molly Meyer, LLC is a green roof design and consulting firm. Rooftop Green Works, LLC is a contracting company specializing in the installation and maintenance of vegetated green roofs. EcoKnowledge Nexus, LLC provides on-going education on green building topics to professionals in the green building industry. In 2007, she received a fellowship from the Robert Bosch Foundation to work in the vegetated green roofing industry in Germany. She installed all varieties of green roofs (including sloped, single-course extensive, multi-course extensive, intensive, and inverted roofs), analyzed existing green roofs for maintenance issues, and designed green roof systems including wind uplift, drainage, irrigation, and sloped applications. She is bringing her unique and rich experience in the mature green roofing industry in Germany to the young green roofing industry in the U.S. Molly's construction work began in 2005 when she was an apprentice carpenter for general contractor Edifice Construction in Seattle. She earned her B.S. and M.S. in Earth Systems, with a focus in soil research, from Stanford University. She currently lives in Chicago, Illinois and is originally from Indianapolis, Indiana.

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QUIZ QUESTIONS

1. Which of the following are benefits of vegetated green roofs:
   a. Reduce urban heat island effect
   b. Increase lifetime of roofing membranes
   c. Mitigate stormwater runoff
   d. All of the above

2. How much is a building's air conditioning demand reduced due to a green roof?
   a. 5 %
   b. 10 %
   c. 25 %
   d. 50 %

3. An extensive green roof has a total system depth of less than seven inches.
   a) True
   b) False

4. What is the typical saturated weight for an intensive green roof?
   a. 10-35 lbs/sf
   b. 35-50 lbs/sf
   c. 35-100 lbs/sf

5. In a built-in-place system, each layer is installed individually.
   a) True
   b) False

6. Which of the following is NOT the same for modular and built-in-place systems:
   a. Can be used on extensive roofs
   b. Can be instantly green, with more than 80 percent plant coverage on the day of installation
   c. Can be installed on roofs with limited access
   d. Can be removed if there is a leak in the underlying roof membrane

7. What is the acronym of the green roof guidelines developed in Germany?
   a. FLL
   b. EGR
   c. FGR
   d. GRB

8. In what decade was there a federal ruling in Germany prohibiting the unification of water and sewage fees?
   a. 1970s
   b. 1980s
   c. 1990s
   d. 2000s

9. Green roof material costs are higher in Germany than in the U.S.
   a) True
   b) False

10. Which of the following is a potential green roof failure?
    a. Membrane leak
    b. Structural collapse
    c. Unwanted plant growth
    d. Too little water
    e. All of the above

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