# Reroofing Green

***By Richard P. Kadlubowski***

Seen from the air, the contemporary urban landscape is changing. No longer solid swathes of grey and black, cities are ever more dotted with lively patches of green—the vibrant foliage of roof and plaza plantings. And these green roofs aren't always what you might expect. Not just for opulent penthouse gardens or costly environmental experiments, landscaped roofs and plazas adorn structures ranging from public housing projects to city halls to corporate headquarters, and they're gaining momentum. In the current drive to reduce energy consumption and protect against rising temperatures, even the most modest green roofing projects stand out as real and lasting solutions. Is your roof ready? Here's a look at some options and considerations.

## What Is a Green Roof?

When we picture a traditional garden on a roof, with grasses, flowers, shrubs, or trees, what we are likely imagining is an ***intensive green roof***. These gardens are designed as usable space, and must therefore accommodate significant amounts of foot traffic beyond that of maintenance crews. Growing media tend to be deep (a foot or more) and dense in organic material (45–50%), with fully saturated weights of 80–120 lbs./sq. ft. and up. Adding this type of green roof to an existing structure can require significant restructuring or augmentation of the roof deck, so a thorough structural analysis is imperative.

A lower-maintenance, lower-cost alternative is the ***extensive green roof***. Here, plants are selected for their resistance to high heat and drought, as well as for their shallow root systems and water retention. Sedum and native grasses and flowers are commonly used options. With limited access and shallow growing media, these roofs add fully saturated weights of closer to 30–50 lbs./sq. ft.—still significantly more than a standard roof (usually 1–15 lbs./sq. ft.), but more manageable than an intensive roof garden. Planting media

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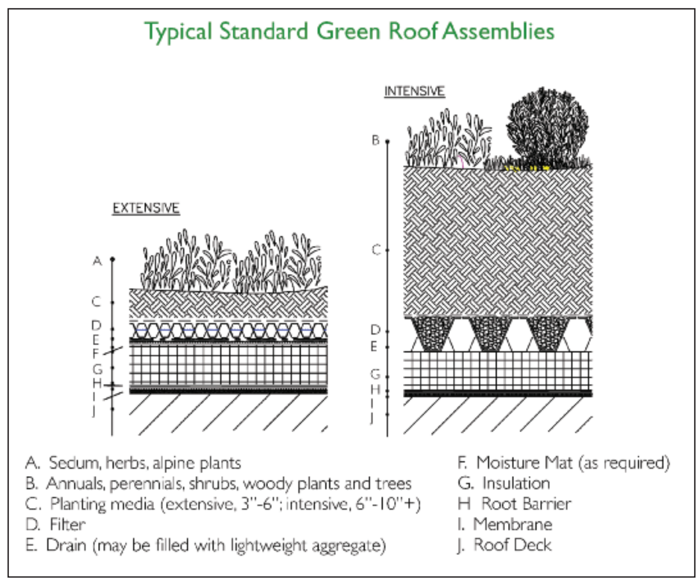
*Gardens atop Rockefeller Center buildings—among the first and most well-known green roofs in New York City.*

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## Green Roof History

Modern green roofs, composed of layers of waterproofing membranes, root barriers, growing media, and vegetation, were popularized relatively recently, beginning in Germany in the 1960s. Still, the concept is not new. The Hanging Gardens of Babylon were built around 600 BC, and Scandinavian countries have traditionally covered their pitched roofs with grass since the time of the Vikings. The following timeline marks key moments in the contemporary movement toward greening America's roof landscapes:

**1961**

Dr. Reinhard Bornkamm of Berlin, Germany's Free University publishes his groundbreaking work on green roofs.

with high inorganic content (70–80%) and low plant heights contribute to a reduced load. And, unlike a traditional garden, extensive green roofs can have slopes of up to 30°; steeper slopes can be achieved using grids or lathes to hold the plants and growing matter in place.

While extensive green roofs may offer a more practical option for retrofit projects than do intensive roof gardens, a qualified design team must first assess whether an existing structure can be safely redesigned to withstand the additional load.

## Why a Green Roof?

When faced with a deteriorating roof, most owners and managers have three prime concerns when assessing re-roofing options: cost, longevity, and performance. Each re-roofing project is unique, with special considerations depending on type of construction, location, climate, and building use. A qualified design professional can assess individual requirements and help building owners or managers to select the right solution for their re-roofing needs.

While the initial cost of installing a green roof may seem prohibitive (it can be twice as much as conventional options), don't rule it out. Green roofs also last twice as long as most standard roofs, which require replacement every 15–20 years. Some green roofs in Germany, where green roof technology was pioneered, have lasted 40 years without needing replacement. And the long-term benefits are many. Some to consider:

**Energy Savings.** On a 95°F day, the temperature of a conventional roof can be about 158°F. On a green roof, the temperature would be closer to 77°F. Why? In the process of evapotranspiration, plants use heat energy from their surroundings when evaporating water, cooling the surrounding air. That translates into as much as a 25% reduction in summertime cooling costs. If more cities were covered with green, we would see less power-grid loading and lower summertime power prices; currently, a full 1/6 of US energy is used to cool buildings. In the winter, green roofs provide added insulation with 18% less heat loss than with conventional roofing.

**Noise Reduction.** Plants, growing matter, and trapped air and moisture in soil are excellent insulators, not just thermally, but acoustically, too. Some studies have shown that green roofs can reduce outdoor noise heard inside the building by 40 decibels or more, depending on the depth and nature of the substrate. In busy city centers or near traffic, machinery, or airplanes, buildings with green roofing offer their occupants a respite from noise pollution.

**Preservation of Roof Waterproofing.** Bare roofing membranes, which are subjected to extremes of temperature and intense direct sunlight, deteriorate more quickly than do those protected by plantings. Not only do plants moderate the air temperature, but their leaves also disperse the sunlight that would otherwise impinge directly on waterproofing materials. This layer of protection adds up to longer material lifespan—and reduced membrane maintenance and replacement costs.

**Water Runoff Management.** The job of a conventional roof in a rainstorm is to drain water as quickly as possible, as any pooled water can mean leaks. When a city is hit with significant rainfall, all the buildings, not to mention roads and sidewalks, are unloading water at once; sometimes, enough to overwhelm the city's sewer system. This can lead to backups and even raw sewage dumping into the waterways. Depending on the plants and growing medium used, green roofs can retain up to 90% of rainwater. Any runoff is then released slowly as it's filtered by the plants, reducing stress on sewer systems during peak flow periods.

**Moderated Heat Island Effect.** The "Heat Island Effect" occurs when asphalt, tar, and concrete trap heat and raise the temperature of dense urban areas in relation to the surrounding rural countryside—as much as 10–15°F. This rising bubble of hot air over cities creates artificial air currents that then contribute to smog, ozone, and dust. Green roofs' heat-absorbing properties not only benefit the owner and occupants with reduced energy costs, but also offset the Heat Island Effect and provide a cooler microclimate for the surrounding community.

**Health and Habitat.** Occupants and those in the surrounding community will enjoy not only the health benefits of improved air and water quality afforded by green design, but also the aesthetic advantage of a greener landscape. And building owners and managers appreciate the eye-catching appeal of a standout green roof, which can increase property values significantly.

*Schwab Rehabilitation Hospital, Chicago, Illinois.*

**1971**

Gerda Gollwitzer and Werner Wirsing, German landscape architects, pioneer modern green roof design, backed by study and testing of materials, in their book, *Roof Areas Inhabited, Viable, and Covered by Vegetation*.

**1975**

The Landscape Research, Development & Construction Society is founded in Mainz, Germany and establishes green roof standards.

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Even green roofs that aren't designed for recreation enhance the local environment by becoming home to local birds and insects. Some demonstration projects and designs have featured restored local habitats in areas where natural ecosystems are dwindling. These roofscapes attract the attention not only of wildlife, but of the press and others in the community.

**Government Incentives.** Rising energy demands and concerns about smog and other pollution have led many local governments to offer incentives for sustainable building methods, including green roofing systems. States and municipalities benefit greatly from the improved storm-water management, reduced energy demands, and mitigated pollution provided by green roofs, and often encourage such projects through grants, credits, and fee waivers.

In some areas—notably Chicago and Washington, D.C.—building owners can take advantage of tax breaks and funding that may help offset the higher initial costs associated with a green roofing project. New York, Oregon, California, and Maryland have also implemented incentive programs, and other states and cities are following suit. As part of the investigative phase of a green roof project, a design professional can help determine which, if any, of these cost savings apply to your building.

## Structural Concerns

While green roofs offer real benefits, they also present some special concerns. Water, plants, growing media, planters, root barriers, and other materials add significant load to a building's structural support, even in a relatively lightweight extensive roof garden.

### Roof Loading

When properly designed and constructed, roofs, as well as plazas and terraces, should be capable of carrying the required dead and live loads.

The ***dead load*** is the weight of all materials of construction incorporated into the building, which includes walls, floors, roofs, ceilings, stairways, built-in partitions, finishes, cladding, and other similarly integrated architectural and structural components, as well as fixed service equipment. With respect to roofs and plazas, the dead load also accounts for waterproofing systems and associated coverings (e.g., ballast, pavers), and may include planters and benches if they are part of the original design.

By contrast, ***live loads*** fluctuate with building use, and are generated during the life of a structure by people and moveable objects. A roof that sees only maintenance crews and equipment would have a considerably smaller live load than one with significant foot traffic.

In addition to dead and live loads, the building design must also accommodate construction loads and environmental loads, such as those caused by wind, rain, or snow. Depending on the building's geographical location, the design may need to account for earthquake or flood loading as well. Roofs and plazas in northern climates experience greater snow loads than do those in the south, and winds in coastal regions would impart more load than those further

COURTESY OF LIVEROOF, LLC

*In a modular system, such as the LiveRoof system pictured here, plants are grown to maturity offsite in recycled plastic modules, which are then set tightly together for a uniform appearance.*

**1998**

The Business Week/Architectural Record Award applauds environmentally sound design at Gap Inc.'s grass-covered California headquarters, built in 1997.

After observing green roofs in Germany, Chicago Mayor Richard M. Daley subsidizes green-roof projects and research with municipal funds.

The U.S. Green Building Council creates the LEED rating system (Leadership in Energy and Environmental Design), which offers points for green roofs.

**1999**

Green Roofs for Healthy Cities is formed in Toronto, Canada to promote construction of green roofs in North America.

inland. Building configuration, as well as environment, must be taken into account; whether the roof is flat, sloped, open, or congested with numerous projections also affects snow and wind loading.

Most structures were designed to support the required dead and live loads for their building configuration, location, and function—but little more. To retrofit an existing roof deck with growing media, plants, and containers, augmentation of the structure may be necessary to accommodate the additional loads and prevent serious structural failure.

### How to Strengthen an Existing Deck

A structural evaluation is critical prior to undertaking any project that would exceed current design loads. Once the existing building's capacity and new load requirements have been determined, additional structural support can be tailored to the type of construction.

For all types of decks, the additional loads for a rooftop or terrace garden would need to be transferred to the bearing points (generally columns and walls), and then to every level below, down to the footings. Providing additional bracing from only the floor below would not provide true structural support to the new load.

Green roof components such as drainage, water-retention mats, and soil must be considered at their saturated weights in order to calculate the additional loading. Increased foot traffic and irrigation/maintenance equipment must also be evaluated, as well as changes in wind, snow, or rain loading in the new design.

Methods for strengthening decks vary by type of construction, configuration, and environment. Steel decks may require additional support from below in the form of additional beams or trusses, whereas concrete decks may need new connection supports at columns, or augmentation with a steel support section. A qualified architect or engineer can determine how much additional support the green roof will need, as well as the most efficient, cost-effective, and secure way to direct the increased load down to the base of the building.

## Waterproofing Concerns

Unlike a traditional roof, a green roof needs some degree of moisture saturation in order for plants to thrive. The goal of waterproofing in either case is to keep water out of occupied spaces; on a green roof, however, water does not channel immediately to drains, but instead filters through the planting media. In a well-balanced system, plantings and soil absorb moisture before it can reach the roofing membrane, while any excess water drains away without over-saturating the system. Still, the level of moisture in a vegetated roof covering presents challenges, in that the constant presence of water can be a potential source of leaks.

In a green roof project, as with plazas and terraces, the roofing membrane is buried below tons of plantings, soil, drainage media, pavers, and other aesthetic elements, making it extremely difficult, costly, and time-consuming to locate the source of a leak and correct it. In all roofing jobs, waterproofing is a critical component, but it is even more so with a green roof, where there is little room for error in membrane and system choice or installation.

The keys to success include specifying the right roofing system, selecting a capable contractor, and having a quality-control representative onsite to confirm that construction adheres to the details and specifications. Once the roofing system is in place, extensive flood testing should be completed to confirm the membrane's integrity prior to adding the overburden and green components.

### Waterproofing Systems

Just as with traditional roofs, there are many choices of waterproofing membranes on the market for green roof applications. These may be organized into three basic categories: sheet (includes single-plies, thermal plastics, and rubber membranes), built-up (includes MBR and typical BUR systems), and fluid-applied (hot or cold, asphaltic, acrylic, or epoxy).

**Sheet systems** have sheets of membrane that are adhered to the deck, which then require some type of seaming process to bind the pieces together. Depending on the material, the seams may be glued, taped, or welded. The quality of the seam is dependent on the applicator.

Most sheet membranes have reinforcing to resist puncture, but because sheet membranes typically have no self-healing properties, any tears that do occur remain until repaired. Adhesion to the deck prevents moisture from traveling, localizing leaks and minimizing costly and difficult searches for the water infiltration source.

**Built-up systems**, as the name implies, are installed by laying down multiple smaller sheets of material and bonding them in layers of hot asphalt, coal-tar pitch, or

**2001**

The country's first municipal green roof is installed on Chicago's city hall.

*LDS Assembly Hall, Salt Lake City, Utah.*

**2003**

Atlanta installs the first municipally-owned green roof in the Southeast on its city hall.

Ford's assembly plant in Michigan adds one of the world's largest green roofs, now a tourist attraction.

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cold adhesives. The multiple layers provide a level of redundancy not found in monolithic systems, and they offer both puncture resistance and self-sealing properties. Applying the system directly to the deck helps to keep any leaks that do occur localized for easier repair.

**Fluid-applied systems** are similar to built-up systems in that reinforcing and binders are used to produce the final membrane. However, with the liquid-applied systems, the binder/membrane fluid itself is the primary waterproofing. Installation involves application of the liquid membrane to the deck, then the addition of reinforcing to increase strength and puncture resistance, while the layer is still wet. A second layer of fluid is then applied over the first. When the installation is complete, a monolithic, no-seam membrane is achieved.

### Making the Right Choice

Some factors that enter into the decision:

- **Strength.** Although protection mats and root barriers keep plants from impinging on the waterproofing system, reinforced membranes offer an added degree of impenetrability.
- **Resilience.** A waterproofing system without seams would eliminate initial points of water entry.
- **Ease of repair.** Waterproofing that is fully bonded to the deck would keep any moisture that does penetrate the system from travelling beneath the membrane. It's easier to fix a leak if you can readily find its source.
- **Self-healing properties.** Due to the flow characteristics of the material, bitumen-based systems can often recover from small punctures without intervention.

A good choice in many applications would therefore be monolithic, fluid-applied, bitumen-based waterproofing membranes. These resilient, self-healing systems balance ease of application, durability, and compatibility with overlying planting matter. Each roof is different, however, so an individualized assessment of existing construction, in light of project goals, is essential.

### Costs and Concerns

Green roof projects can be expensive, and it can be tempting to cut costs in this phase of the project by opting for a low-bid contractor or neglecting quality-control oversight. However, choosing the right roofing system is not enough. Proper methodology and detailing, particularly along the perimeter and at penetrations, save money in the long term by preventing failure of the waterproofing system down the road. An experienced design professional can help building owners and managers select the right contractor, oversee the roofing installation, and provide quality-control testing to see the project through to successful completion.

Cost savings can be realized on many elements of a green roofing project. Cutting corners on the waterproofing process, however, may mean an expensive and disruptive repair project in the near future, when planters, pavers, soil, and vegetation must be removed to remedy a water infiltration problem that might have been prevented. Waterproofing prudently from the outset will provide years of hassle-free, low-cost roof maintenance, while plantings protect the membrane—rather than cover its problems.

## Selecting a Planting System

### System Components

In a typical traditional roof assembly, there are generally four layers: substrate (roof deck), insulation, membrane, and ballast or coating. Green roofs may have nine or more layers, including:

- Substrate (deck)
- Insulation
- Waterproofing membrane
- Protection board or fabric
- Root barrier
- Drainage media (drainage board or gravel)
- Moisture retention material
- Growth media (soil)
- Plantings

Depending on the type of green roof—extensive or intensive—additional or fewer layers may be required. The sequence of the assembly may also differ, as, for example, when the membrane is applied directly to the substrate, with insulation atop the membrane.

**2004**

Millennium Park in Chicago becomes an immense green roof, extending 24.5 acres over underground parking garages.

*Mashantucket Pequot Museum, Mashantucket, Connecticut.*

**2008**

Opening of the California Academy of Sciences building, which includes a 2.5 acre green roof of native vegetation, designed as a habitat for indigenous species.

Green roof systems may be modular, with drainage layer, filter, and growing media prepared offsite in moveable, interlocking containers. In other cases, each component of the system is installed separately, and plantings are cultivated in the completed roof assembly. An advantage of the former is that the roof will be "green" immediately upon installation. However, these systems are generally only for extensive roof gardens; larger plantings (such as trees and shrubs), those that require more maintenance (flowers and grass), or those accessed by the public may necessitate grown-in-place, multi-layer systems.

STEPHEN LEE, COURTESY OF RICHARD BURCK ASSOCIATES/LANDSCAPE ARCHITECT

*This extensive green roof assembly, above a one-story parking garage, places succulents, sedums, and* della spirna *plantings over a fluid-applied, direct-bonded, monolithic membrane.*

Before choosing a planting system, consider the deck slope and existing electrical and water infrastructure. Some green roof designs may accommodate a greater range of slopes and still achieve proper drainage. Irrigation and other maintenance systems will also need to be considered at the time of installation. Options for a retrofit green roof project may be limited by the building's structural loading capacity, levels of sun or wind exposure, existing waterproofing system, or other intrinsic factors, as well as by budgetary and logistical constraints.

### Vegetation and Design

Plant selection depends on a variety of factors. Some to consider:

- Climate
- Sun and wind exposure
- Type and depth of growing medium
- Loading capacity
- Height and slope of the roof deck
- Maintenance expectations
- Irrigation
- Aesthetics

While gardens of grass and trees are possible on a rooftop, these necessitate constant upkeep, as well as costly irrigation systems. Other roof gardens cultivate minimal-maintenance native plants, which mimic local habitats and can become home to birds, butterflies, and insects. Some roofs or terraces have even been used for urban agriculture, providing fresh produce to restaurant and hotel guests, or residents inside the building.

A popular type of vegetation for extensive roof gardens is sedum, a low-maintenance plant that is heat- and drought-resistant—important qualities in the baking temperatures of a rooftop. Its shallow root system means less depth of growing media, yet it holds a high percentage of rainwater. More absorption means less runoff, which reduces the burden on drainage systems. Sedum is also popular because it is so easy to grow and maintain; although initial irrigation is necessary to establish the plantings, once the system is in place, it is essentially self-sustaining.

## Challenges of Green Roof Projects

Green roofs and, similarly, terraces and plazas over occupied spaces, present special rehabilitation issues that are generally not concerns in other horizontal waterproofing projects, such as parking decks or traditional roofs. A sampling:

**Aesthetic Requirements.** A green roof becomes part of the structure's aesthetic character, acting as a "fifth façade" that's as visible to the public as any other building face. While most green roofs are more ecological powerhouse than garden, they still draw the public eye and so demand attention to detail. This is true of any green roof, but is especially true of those open to more than maintenance traffic.

**Exposure to Traffic.** Like plazas and terraces, intensive green roofs see significant foot traffic, creating the threat of potential damage to waterproofing membranes, even if they are protected.

**Safety Concerns.** Traditional roofs are exposed to relatively little traffic, except from contractors and maintenance personnel experienced with roof safety. On a green roof used by the public, however, tripping hazards and other sources of potential injury must be vigilantly monitored. Even extensive green roofs present additional safety concerns, as maintenance workers must negotiate narrower walkways and, depending on the system, irrigation and other equipment.

**Increased Loading.** People, pavers, planters, growing media, and maintenance equipment put stresses on the building beyond those in a typical roof installation. Green roofs need special consideration of load-bearing capacity.

**Waterproofing Issues.** Vegetation and growth systems create unique waterproofing problems and affect drainage. Gaining access to the waterproofing layer is much more complicated and expensive on a green roof, because the entire planting system must first be removed. Although top-quality performance is required in all horizontal waterproofing projects, green roofs require a particularly conservative approach.

**Flashing Design.** While flashing is a potential weak point in any waterproofing job, it presents added concerns in a green roof project, where it is often expected to occur below the vegetation level, or to be hidden in some other way.

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*Laying sedum on an extensive green roof.*

**Debris Removal.** To rehabilitate a green roof, considerably more material must be removed from the site than in a typical roofing project. Plants and growing media, planters, and pavers must all be removed to access the waterproofing membrane. In a dense urban setting, or in an occupied building, noise and dust must be minimized over a considerable period of time, generating costs and logistical challenges not encountered in traditional roof rehabilitations. For this reason, it's especially critical to waterproof a green roof properly at the time of installation.

**Plantings.** Selecting and maintaining plantings and appropriate growing media that can withstand rooftop conditions without exceeding the structural design load is a critical component of the "greening" process. Should roof repairs become necessary, plantings may need to be restored or replaced after rehabilitation work is complete.

**Costs.** Green roofs can be more than double the price of traditional roofs to install and rehabilitate. However, energy savings and waterproofing membrane protection, in addition to government incentives, can help to offset some of the additional expense.

## The View from the Top

A green roof provides benefits on many levels: economic, including reduced heating and cooling costs and extended roofing membrane lifespan; social, such as improved health and surroundings; and environmental, including water runoff management and a reduced heat island effect. Corporations and municipalities that "go green" have been cited as leaders in the conservation movement, and their buildings have received much attention in the press. With the drive to reduce energy consumption, decrease global warming, and protect our air and waterways from pollution, building practices have looked to innovative designs to reduce environmental impact.

Before embarking on a green roofing retrofit project, consult an experienced design professional to assess the structural capacity of your building, and to evaluate the waterproofing and planting system options. A green roof is a significant expense, so a properly suited design and proficient installation are critical to the long-term success of the project. With the right guidance, a green roof can be an eye-catching asset with great returns on the initial investment, both for the individual building owner and for the community. 🏛

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