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Journal

Green Options in Roof Replacement

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With New York City's "80 by 50" initiative to reduce greenhouse gas emissions 80% by 2050, the stakes are high for the city to adopt progressively more stringent energy codes. Similarly, the Sustainable DC Plan professes the lofty goal of making the nation's capital "the greenest, healthiest, and most livable city in the nation." Other states and cities are following suit, as building owners, managers, and the design and construction industry race to keep up with the rapidly evolving codes, energy analysis requirements, and documentation standards.

Vegetative roofs can be an attractive amenity, creating a pleasing outdoor space and adding value to the building.

For their part, manufacturers are responding with a flood of new products and technologies to meet the stricter energy efficiency requirements, and while options abound that address the insulation, reflectance, durability, and moisture management properties stipulated by the new laws, choosing the right option for the building and situation can be daunting.

While this may seem an unprecedented upheaval in the building industry, reroofing an existing building has always posed similar challenges. Even if the energy codes do bring new terminology and processes, the roofing industry has always been a moving target, with product innovations that rapidly make even a five-year-old low-slope roof seem eons behind its newer counterparts. Fortunately, the process of selecting and designing a code-compliant roof replacement remains much the same as it always has: evaluate the existing building to determine compatible options; compare those options in terms of cost, performance, aesthetics, functionality, and other criteria; and design and detail the new roof to address structural and waterproofing conditions.

Far from a passing trend, the sustainable building movement has made lasting changes to the expectations for new roof systems, and while these changes can take some getting used to, the focus on ecological roof technology does provide building owners and managers with new options for reroofing that can reduce heating and cooling demands, improve indoor comfort, and even increase the projected lifespan of the roof assembly. Becoming familiar with the pros and cons of different types of sustainable roofing takes the guesswork out of choosing a system that meets performance and energy standards and creates a positive image for the building.

Stephanie L. Dillon, Assoc. AIA, Project Manager, designs green roof replacements for buildings ranging from universities to corporate headquarters. Kristin R. Holtgrew, Assoc. AIA LEED AP, Senior Project Coordinator, applies her background and credentials in sustainable design to developing ecological reroofing solutions.

Installation of planting medium around a large shrub on an intensive green roof.

Vegetative Roofs

The poster child for green building, vegetative roofs are subject to all of the same enthusiasm, scorn, hype, and derision that has followed the push for sustainable design since the creation of the Leadership in Energy and Environmental Design (LEED) rating system in the late 1990s. As government projects and private industry experimented with new systems, green roof assemblies improved, with scientific papers documenting best practices for everything from plant selection to waterproofing details. Early missteps that resulted in fields of scorched, brown sticks plagued early adopters of green roof technology, but those problems are largely behind us.

After nearly 15 years since Mayor Daly installed the nation's first municipal green roof on Chicago's City Hall, many more examples of thriving vegetated assemblies (and others that haven't exactly flourished) have helped to further refine approaches to creating a living roof. Today's vegetative roof options have the benefit of longer in-service evaluation, and they run the gamut from economical prefabricated tray systems to custom landscaped roof terraces.

Although green roofs cost more than traditional roofing assemblies, they have the potential to add value to an existing building by replacing utilitarian roofs and setbacks with something eye-catching.

Roof Gardens and Terraces

When we picture a rooftop oasis over occupied space, such as the widely publicized Terminal 5 Rooftop at John F. Kennedy International Airport, where people meander along a plaza stocked with foliage and furniture, what we are envisioning is an *intensive green roof,* so called because it often is labor-intensive, both in terms of initial installation and in ongoing irrigation and maintenance.

Intensive green roofs can act as an extension of the building, adding attractive usable space where there might otherwise be a blank stretch of featureless roof membrane. As an amenity, intensive green roofs can capitalize on unused portions of an existing building, and they have the added benefit of drawing positive attention to building envelope retrofits by showcasing the building owner's commitment to environmentalism, sustainability, and the well-being of tenants and building users.

To accommodate trees and other large plantings, growing media for intensive roof gardens tends to be deep (a foot or more, depending upon the desired vegetation), with soil dense in organic material and fully saturated weights of 80 to over 120 pounds per square foot. Add to that plant matter

Remediating a leak on a green roof involves removal of plants and overburden.

Intensive green roofs often require supplemental irrigation.

the weight of pavers, fixtures, furniture, and decorative elements, along with the live load of visitors and maintenance personnel and equipment, and you have significant structural considerations for an existing building. (For more on structural concerns, see "Is a Vegetative Roof Right for Your Building?" on the facing page.)

Extensive Landscaped Roofs

A lighter-weight, low-maintenance option is an *extensive green roof*. Although it does not provide the added usable space that an intensive green roof does, an extensive assembly offers many of the benefits of a vegetative roof with a lower structural load, minimal upkeep, and a greatly reduced cost over intensive systems.

To keep loading to a minimum, extensive systems use shallow growing media with high inorganic content that tends to have a much lower saturated weight (roughly 15 to 50 pounds per square foot) than that of an intensive green roof. Sedum, native grasses, and other hardy plants that are drought- and heat-tolerant allow extensive green roofs to flourish without supplementary irrigation. Although the weight of even an extensive green roof is still more than that of a traditional built-up or single-ply roof, these shallow, self-sustaining vegetative systems are often readily manageable as a retrofit option for existing buildings,

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Is a Vegetative Roof Right for Your Building?

Beyond the obvious aesthetic appeal of rooftop greenery, vegetative roofs offer real benefits, both to the building owner and to the larger community.

Energy Savings. By modulating rooftop temperatures through *evapotranspiration,* the evaporative cooling caused by the movement of water through plants, green roofs keep the roof and the surrounding air cool. In winter, the growing media and plant matter act as insulators, protecting against heat loss.

Longer Waterproofing Service Life. Moderating rooftop temperatures also protects the roof waterproofing from extremes of heat and cold, and the plant covering prevents direct sunlight from degrading the roof membrane. Although the growing media and vegetation can make leaks more difficult to locate and repair, if the waterproofing system is designed and installed properly, the plantings offer protection from the wear and tear of direct exposure to the elements.

Stormwater Retention. As part of many cities' efforts to combat sewer system overload, building codes are increasingly calling for provisions for stormwater management. In New York City, for example, the NYC Green Infrastructure Plan requires greater onsite storage of stormwater runoff and slower release to the sewer system, in order to reduce peak discharges during rain events. Here, too, vegetative roofs have an advantage over conventional systems; plants and soil naturally retain and filter rainwater, releasing runoff slowly over time.

Habitat and Environment. In large cities where vegetated areas are few and far between, roofs offer an opportunity to create a natural oasis in even a dense urban setting. Some extensive green roofs have been designed to replicate local ecosystems and serve as a waystation for migrating birds and butterflies. A view of greenery or access to an outdoor garden has been shown to improve patient outcomes in hospitals, increase productivity in offices, improve academic success in educational settings, and have a general positive impact on health and well-being.

Although the positive environmental and practical value of a well-designed, properly maintained green roof has been well documented over the past decade, there are real considerations for any building owner or manager when making the decision to replace a traditional low-slope roof with a vegetated one.

Structural Concerns. Before opting to add a vegetative roof to an existing building, consult an engineer to conduct a structural evaluation of the existing roof. The analysis should consider the saturated weight of the components, along with the load from increased foot traffic and additional maintenance equipment. Adding a vegetative assembly could also impact wind, snow, and rain design loads, so these modifications should be taken into consideration as part of the structural calculations.

Waterproofing Design. Selecting the right waterproofing system is especially critical with vegetative roofs. Once the roofing membrane is buried below plantings, soil, drainage media, pavers, root barrier, irrigation systems, and other elements, it is difficult and expensive to locate and repair a leak. A resilient, multi-layered system that is durable and compatible with overlying plant matter is critical to the long-term durability of any vegetative roof system. To confirm water-tightness of the membrane, flood testing or other methods of leak detection are recommended prior to installation of green roof components. ■

The rehabilitated garden roof terrace at this university student union provides appealing green space for dining, outdoor performances, and other leisure activities.

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as they tend to require little, if any, structural modifications.

Even pitched roofs can be fitted with extensive green roofs; some prefabricated tray systems are designed to accommodate slopes of up to 30 degrees, and steeper grades can be managed using grids or lathes to secure the trays in place.

As the emblem of the green building movement, vegetative roofs are an important option for sustainable reroofing projects. But they aren't the only choice. If waiting for a roof garden to germinate and grow is not feasible, or if maintaining plantings on a 48th-floor setback is impractical, or even if the structure just won't tolerate the additional load, then it is worthwhile considering other systems that are more like a traditional low-slope roof, but with energy-saving perks.

Cool Roofs

What makes a "cool" roof sustainable? Also known as "reflective roofs" or "white roofs," cool roofs have a high *solar reflectance* or *albedo*, which means that they reflect sunlight much better than a traditional roof does. By radiating energy back into the atmosphere, cool roofs' high *thermal emittance* allows them to reduce solar heat loads on the building. Like green roofs, cool roofs help to reduce the trapped heat in urban areas known as the "heat island effect," which in turn cuts levels of air pollutants that contribute to smog.

Edge detailing is just as important on a cool roof as on a conventional one.

> "Even in colder climates, cool roofs can significantly reduce peak energy demand."

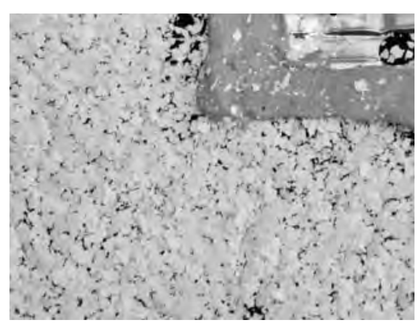
Energy Codes and Performance Requirements

In response to concerns that reflective roof surfaces in northern climates actually *increased* energy consumption by requiring additional heating in the winter months, ASHRAE 90.1, the energy standard that serves as the model code for many states, revised their roofing standards in the 2010 edition to specify cool roofs only in warm climates. However, there is some contradictory evidence that cool roofs can reduce energy consumption across all North American climate zones.

According to a recent study by the Oak Ridge National Laboratory, even in colder climates, cool roofs can significantly reduce peak energy demand. When installed with appropriate insulation, cool roofs were shown to cut peak energy use enough to compensate for increases in winter heating caused by the roof reflectivity, resulting in an overall net energy savings. However, this energy savings may depend on other factors, including whole building envelope thermal performance and type of heating fuel used. To guide building owners, managers, and project teams in determining potential energy savings, the Department of Energy provides an online tool, the "Cool Roof Peak Calculator," for low-slope commercial and institutional roof assemblies.

Energy use calculations aside, the decision to install a cool roof on a building may be mandated by code. The 2014 New York City Building Code requires that new roof coverings on all low-slope roofs (less than 17 percent grade) meet minimum reflectance requirements, with the exception of vegetative roofs and other types of landscaped areas or usable plazas, very small terraces or setbacks, areas under rooftop equipment, roofs used as playgrounds, certain roof types, and other case-specific instances. The New York City Energy Conservation Code adopted in January 2015 also incorporates requirements for roof reflectivity, with tables for acceptable solar reflectance and thermal emittance values.

Similarly, the Washington DC Energy Conservation Code, based on the 2012 International Energy Conservation Code, includes stipulations for reflective roofs. According to the Cool Roof Rating Council, dozens of other states and cities, including Connecticut, Delaware, Massachusetts, Maryland, New Jersey, Virginia, Pennsylvania, New Hampshire, and Rhode Island, have adopted ASHRAE or International Energy Conservation Code (IECC) standards that include provisions mandating cool roofs.



Reflective granules on a high-albedo cap sheet direct solar heat away from the roof.

Roof Insulation Requirements

In the drive toward net-zero energy buildings and ever-greater energy efficiency, expectations for building performance have rapidly progressed over the past several years. With each successive iteration of ASHRAE 90.1 and the International Energy Conservation Code (IECC), the generally accepted national energy standards, requirements for building envelope thermal performance have become increasingly stringent, and they will likely continue to do so for some time to come. For this reason, roof insulation considerations are an essential part of any reroofing project.

In 2006, the IECC recommended a roof insulation R-value of 15 for commercial buildings in most North American climate zones. Just six years later, in the 2012 edition, that R-value jumped to 20 for southern states and to 25 for most of the rest of the country, with the far northern states having insulation requirements as high as 30 to 35. *R-value* is a measure of a materials' resistance to heat transfer and is the reciprocal of *U-factor,* which describes how well an assembly conducts heat. The higher the R-value of a building element, the better it is at protecting against heat loss.

For reroofing projects on existing buildings, meeting increasingly rigorous insulation requirements can be a challenge. Even where the project calls for a thin cool roof membrane and not a dense bed of planting media, the depth of insulation necessary to achieve the requisite R-value can impact door thresholds, flashings, walking surface elevations, guardrail heights, edge conditions, and other details. Considering all of these implications during the design phase will help minimize problems in the field, when discovering that increased insulation height won't allow a bulkhead door to open can become a costly last-minute modification. ■

High-Albedo Roof Systems

In response to these codes and standards, and to the increased demand for energy-saving roofing options, roofing manufacturers have increased their product lines for reflective roof assemblies. To meet baseline requirements for current national standards, a cool roof must have a minimum initial *solar reflectance* (fraction of incident solar energy that is reflected by the surface) of 0.70 and *thermal emittance* (measure of a material's ability to release absorbed heat) of 0.75. When aged three years, solar reflectance may be reduced to no less than 0.55, and thermal emittance must remain at 0.70 or greater. Values for solar reflectance and thermal emittance are calculated on a scale of 0 to 1, with 0 being a black roof that absorbs 100 percent of solar energy, and 1 being a perfectly reflective roof.

The *Solar Reflectance Index (SRI)* is a combined measure of solar reflectance and thermal emittance, which rates surfaces from 0 (a standard black surface) to 100 (a reflective white roof). The International Energy Conservation Code and ASHRAE 90.1-2010 stipulate a minimum SRI of 82 at initial installation and 64 for a three-year-aged roof.

The roofing types that best suit these qualifications are:

- Single-ply systems, composed of:
  - Thermoplastic polyolefin (TPO) or
  - White ethylene propylene diene terpolymer (EPDM),
- Modified bitumen roofs (MBR) with reflective granular cap sheets, or
- Fluid-applied reflective assemblies.

Of these, the single-ply systems tend to offer the higher reflectance values, as the membranes are uniformly light in color, with lightweight material that doesn't hold heat. However, single-ply systems lack redundancy and can be prone to seam failure if not installed correctly, so they tend to be less durable and resilient than their multiple-ply counterparts. Although MBR systems do use dark-colored, heat-absorbing bituminous material as the base layers, the granular reflective cap sheet disperses and reflects the majority of solar radiation, preventing heat energy from reaching the layers below.

Single-ply systems tend to be less expensive than MBR assemblies; however,

Dirt and stains from foot traffic can compromise cool roof performance.

Blisters and wrinkles are common problems for sheet membrane assemblies.

Seam failure may create pathways for water infiltration in single-ply systems.

installation may necessitate contractors with special training and equipment, which can add to the total cost. For modified bitumen roof systems with reflective cap sheets, material and installation costs tend to be comparable to those of standard MBRs. Fluid-applied assemblies are monolithic, which eliminates joints and laps in the membrane and so minimizes potential water entry points. Of the three types of roofing considered above, however, fluid-applied systems are typically the most expensive.

Other options for roof coverings with a high solar reflectance index include inverted roof membrane assemblies (IRMA) in which the roof membrane is covered with insulation and reflective pavers, or metal panels with high-SRI finishes. An architect or engineer should advise on the compatibility and effectiveness of any rehabilitation options, as not all products are appropriate for all buildings.

Design Considerations: Reflected Solar Radiation and Glare

Before opting for a cool roof, it is worth preventing future problems by considering not only its impact on the energy use and sustainability of the building on which it will be installed, but of the surrounding buildings, as well. For roof setbacks or roofs surrounded by taller buildings, the assembly needs to be designed in such a way that the reflected sunlight from the roof surface does not create problems with undesirable glare and heat redirected into windows above.

Without appropriate design considerations, reflected heat may negate some of the energy benefits of a cool roof. Some studies have found that temperatures above a reflective roof may be higher than those over a traditional darker-colored roof, which may impact rooftop equipment, conduits, wiring, piping, and other materials subjected to the reflected heat. In some regions, widespread use of cool roofs may have even broader climate implications, as the heat redirected back into the atmosphere may adversely impact rainfall, necessitating appropriate tradeoff measures. As such, owners and design professionals should analyze geographically dependent variables when designing and detailing a cool roof.

Controlling glare and reflected heat continues to be a concern for cool roofs, but that needn't deter building owners and project teams from considering reflective roof materials for reroofing projects. Where code requirements mandate cool roofs, excessive heat gain is unlikely to be a widespread problem, and glare may be managed through low-emissivity window coatings, daylighting controls, baffles, and other architectural elements. Specifying a combination of vegetative and cool roof systems for different roof areas can offer a customized solution that balances comfort with performance.

A Step Ahead

Even where building codes do not mandate increased insulation, cool roofs, green roofs, or other energy-saving assemblies, it is still good practice to opt for roof systems that meet national standards for energy performance. The list of states and municipalities that have newly adopted codes based on ASHRAE or IECC standards is constantly growing, with some cities, such as New York City, enacting energy and building codes that are even more stringent than those at the state level. Rather than chase after evolving requirements, stay at the forefront of energy efficiency policy by choosing assemblies that meet or, better, exceed national standards.

In general, building codes for energy performance are the lowest end of what is acceptable, with plenty of room for improved efficiency beyond what is mandated by law. Increasing insulation levels from 2006 IECC-required values to those mandated in 2012, for example, has been shown to

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representative projects

Ecological Roofing

Whether a reflective roof atop a skyscraper or a vegetated pedestrian garden that extends the building's usable space over occupied stories, the broad meaning of "green roof" can encompass many types of materials and situations. Fortunately, our architects and engineers have experience in designing insulation, waterproofing, drainage, penetration detailing, flashings, and terminations for a wide range of roof systems, from straightforward single-ply membranes on a traditional roof to complex assemblies that can sustain large plants and heavy pedestrian traffic.

Our design professionals have developed sustainable, energy-efficient, code-compliant roof solutions for diverse buildings and settings, including:

State University of New York, Purchase College Social Sciences Building
Purchase, New York
Roof Replacement – Cold-Applied MBR System with Reflective Cap Sheet

Yale-New Haven Hospital 55 Park Street Laboratory
New Haven, Connecticut
Building Envelope Consultation for New Construction – White TPO System

Arburg, Inc. Headquarters
Rocky Hill, Connecticut
Document Review and Construction Administration – White EPDM System

▲ **Yale University, Paul Rudolph Hall (Art + Architecture Building)** in New Haven, Connecticut. *Roof Replacement and New Construction Consultation – Vegetative Roof and Cold-Applied MBR System with Reflective Cap Sheet.*

Connecticut Agricultural Experiment Station Jenkins-Waggoner Laboratory
New Haven, Connecticut
Roof Replacement – White EPDM System

▲ **New Jersey City University, Michael B. Gilligan Student Union** in Jersey City, New Jersey. *Roof Replacement – Intensive Green Roof and MBR System with Reflective Cap Sheet.*

Gracie Mews
New York, New York
Plaza as Green Roof – Intensive Vegetated Usable Space over Parking Garage

Heritage Center I
Annandale, Virginia
Roof Replacement – White TPO System

Fairfield University Barone Campus Center
Fairfield, Connecticut
Investigation and Leak Remediation of Vegetative Roof

▲ **Phoenix Companies Headquarters** in Hartford, Connecticut. *Plaza as Green Roof – Intensive Roof Garden over Offices and Garage.*

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The white cap sheet on this cold-applied modified bitumen roof assembly reflects solar radiation and disperses heat energy away from the building, keeping the interior cool.

have a significant impact on electricity consumption, and installing a cool roof covering over that increased insulation further cuts electric bills by reducing peak demand.

As building performance standards change, so too do the product offerings from manufacturers, which may mean that a straightforward replacement of an existing roof with the same or similar assembly may no longer be an option. Rather than an item to check off the to-do list, reroofing presents the opportunity to consider possibilities for increased efficiency, better indoor comfort, improved building user experience, and enhanced aesthetics. Although some new technologies, particularly green roof systems, do present a greater up-front investment, they can return benefits of long-term durability and create a sustainable building amenity. ■

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