Sustainable Roofing

PHOTO: JOHNS MANVILLE

A Whole-Building Approach

Some newer products such as this TPO sheet, which incorporates PV onto the surface to reduce penetrations, are making rooftop PV a more viable option.

By C.C. Sullivan and Barbara Horwitz-Bennett

Learning Objectives

After reading this article, you should be able to:

- ✔ Describe the basic criteria for green roof performance.
- ✔ Evaluate roofing system and material options based on sustainability, energy efficiency, and durability.
- ✔ Explain the benefits and challenges of green roofs, PV systems, and cool roof materials.
- ✔ Define two types of vegetative planted roofs: extensive and intensive.

What should be the first step toward designing an energy-efficient roofing system? According to sustainability experts, it is to see roof materials and systems as an integral component of the enclosure and the building as a whole.

The roof assembly directly affects such primary environmental variables as the building's heating and cooling loads, vulnerability to moisture, and stormwater management. For those reasons alone, an integrated strategy, such as that advocated by the U.S. Green Building Council's LEED rating program (www.usgbc.org/leed) and the National Institute of Building Sciences' Whole Building Design Guide (www.wbdg.org), is highly desirable. "A whole-building approach is the best way to achieve a sustainable outcome for a project," according to Patrick Thibaudeau, CSI, CCS, LEED AP, HGA Architects and Engineers (www.hga.com), Minneapolis. "Instead of

working in silos of individual disciplines, we advocate integrated cross-disciplinary component teams, with one team focusing on the exterior building envelope."

As part of the firm's integrated process, HGA often employs energy modeling to determine the benefits and energy outcomes of different roofing materials and systems under consideration for a particular project. Such a whole-building approach is particularly important when evaluating options such as vegetated roofing systems, which require a thorough life cycle cost analysis to determine viability. For example, a planted roof carries a higher first cost and has greater demands on the building's structural systems. However, benefits such as improved thermal insulation, longer roofing material life, and more effective rainwater collection and reuse will sometimes outweigh first cost.

All of these factors can best be evaluated and resolved through an integrated design and construction process.

ROOFING SYSTEM PROS AND CONS

In terms of selecting the optimal roof for a given project, the two highest-ranking factors, according to *Building Design+Construction*'s 2011 roofing survey (http://www.bdcnetwork.com/article/how-building-teams-choose-roofing-systems), are durability and energy efficiency. Respondents said they also focus on the following "green" factors:

- Building type
- Location
- First cost and life cycle cost
- Appearance
- Performance requirements
- Service and mechanical access
- Ease of flashing and penetration details
- Green building goals

Adding to this list of roofing considerations, David Cook, principal architect in structural evaluation at CTLGroup (www.ctlgroup.com), Skokie, Ill., poses several questions for roof renovations and retrofits for existing buildings. In the first place, he asks, "What is the existing roof slope? Will the work involve a tear-off, or is it a recladding of an existing roof?" Cook also advises Building Teams to know the structure's original dead-load design ahead of time.

Regarding visual appearance, Cook encourages design and construction professionals to determine how important aesthetics are as early as possible in the project analysis. For example, he asks, will the roof be visible from grade or from nearby highways or buildings?

The ultimate measure of sustainability, however, is how long the roof performs effectively. That means that any performance factor affecting durability is essential to green building. "Don't lose sight of the basics," says Joseph Donovan, AIA, a senior principal with Stantec (www.stantec.com) in New York City. "The most sustainable roof is one that keeps water out of the building."

Specific considerations for roofing selection, based on system type and material attributes, include the following groups. While not a complete list, this sampling includes products that cover a significant majority of U.S. buildings.

Built-up roofing (BUR). An old standard, BUR used to dominate the low-slope roofing market. Considered to be a robust system, its multiple-ply construction offers a good level of redundancy against water infiltration. At the same time, BUR tends to be relatively costly, and the materials may not be compatible with locked-in sites and places where fire and odor restrictions are in effect. In addition, some BUR systems don't rank well environmentally.

"BUR installation requires heating and spreading bitumen as a hot-melt application, which can release VOCs and particulates into the atmosphere," explains Mark Yanowitz, LEED AP, principal of Verdeco Designs (www.verdecodesign.com), a design/build firm based in Andover, Mass. "Adding to that, the heating fuel required on site—typically propane or kerosene—adds considerably to the harmful emissions. In addition, the systems are not easily recycled, as both the insulation and membranes are typically sent to the landfill."

On the other hand, says Stantec's Donovan, a recent presenter at the USGBC's Urban Green Expo, BUR products have come a long way in terms of limiting the release of VOCs and addressing other environmental concerns.

In a similar vein, CTLGroup's Cook, drawing from 30-plus years of facilities- and project-management experience, explains, "BUR reinforcement is recycled paper for organic felt and recycled glass for glass fiber mats. Therefore, the start of BURs is very green because it reuses material or uses production by-products."

Even so, specification rates of BUR recently have been lower than those for more affordable and better-performing alternatives, which some experts say accounts for a gradual erosion of BUR market share over the course of the past decade.

Modified bitumen. Offering greater elasticity and less off-gassing than BUR products, modified bitumen (MB) systems share some of the

PHOTO: COURTESY BRPH

PV laminates adhered to the standing seam metal roof at the Platinum LEED-tracking, BRPH-designed Child Development Center in Pearl Harbor, Hawaii, generate 68% of the building's energy use.

PHOTO: COURTESY HGA ARCHITECTS AND ENGINEERS

HGA's design for the Los Angeles Harbor College Sciences Complex building combines white reflective roofing and BIPV (building-integrated photovoltaic) systems, which provide some shading, thereby reducing solar heat gain.

benefits of BUR, including the redundancy afforded by their multiple-ply structure. Some mod-bit products are recyclable, and a number are manufactured with significant recycled content.

In addition, say experienced project managers, modified bitumen roofing is fairly adaptable. "There are enough variations of hot- and cold-applied systems to meet most conditions," says Gary P. Moshier, AIA, LEED AP, a partner in Pittsburgh's Moshier Studio (www.moshierstudio.com). MB is available in white or light colors to enhance roof reflectivity, which reduces heat gain and HVAC loads. "It can and even work under a modular vegetated roof," he notes.

Single-ply. Single-ply roofing membranes are relatively lightweight and tend to be more straightforward to install than built-up and modified bitumen systems, but they have their critics among the experts. "My biggest problem with single-ply is the single point of failure," says Moshier, a Green Building Alliance board member and adjunct faculty lecturer at Carnegie Mellon University, Pittsburgh.

At the same time, single-ply offerings—such as polyvinyl chloride (PVC), thermoplastic polyolefin (TPO), and other formulations—have improved significantly in recent years and are relatively easy to inspect and repair. According to Thibaudeau, who has served on various green-related AIA committees, single-ply roofs are fairly common. He recommends using Energy Star-rated, fully adhered white or light-colored membranes, as opposed to black materials or ballasted systems.

EPDM. Ethylene propylene diene monomer (EPDM), a member of the single-ply family based on a high-performance synthetic rubber compound, tends to be highly elastic and durable even in severe weather conditions. It also works well on complex roofs with multiple angles and tight corners, says Verdeco Design's Yanowitz.

"In my opinion, EPDM is by far the most economical and best value for new roofing construction," says Victor J. Coppola, an environmental planner with GreenWorks Environmental, a consultant and training firm based in Allenwood, N.J.

Most EPDM products are dark or black, which affords good UV protection though it also means sacrificing the reflectivity that many Building Teams seek for sustainable rooftops. "White EPDM is available, but is not considered as durable and is generally expensive," explains Yanowitz, who has spent the past 25 years in architectural design and construction management.

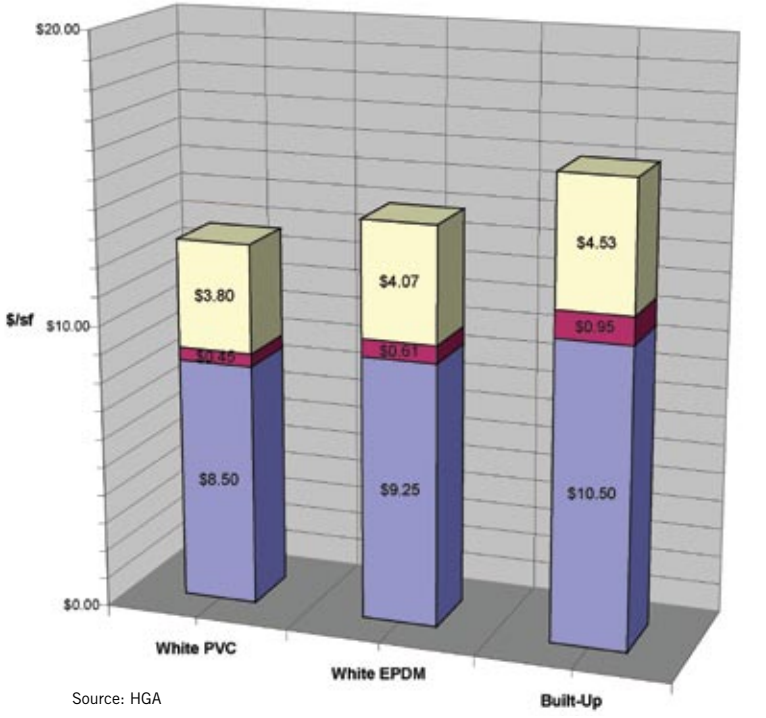
Metal. Moving away from the roll membranes and built-up materials, the most commonly specified roofing system found in *Building Design+Construction*'s survey was metal. According to seasoned building professionals, metal roofing works well for both low-slope and steep-slope roof assemblies. The metal components are fully recyclable and are often made from up to 100% recycled material.

"Considered a very durable and recyclable product, metal roofing's additional cost can be justified by its longer life and the ability to minimize the structural roof-deck requirements, because it spans greater distances," explains Yanowitz. At the same time, seams and joints between metal panels must be carefully detailed to prevent water penetration over time. That is why architect Yanowitz prefers welding over mechanically fastened seams.

Although there is a wide price range for metal systems depending on the application and desired appearance, Moshier and others are pleased

Life Cycle Cost Analysis by Roofing Type

(20-year present value)



Source: HGA

This life cycle cost analysis bar graph compares BUR, white EPDM, and white PVC.

GRAPHIC: COURTESY HGA

PHOTO: COURTESY SOLIS PARTNERS

An integrated cool roof and PV system, designed by solar contractor Solis Partners, was installed at LPS Industries, a flexible packaging company in Moonachie, N.J. Energy management is a key factor in building owners' roofing selection process.

with the availability of newer cool-roof coatings and the compatibility of metal roofs with photovoltaic arrays. "I also like some of the insulated roof panels that can span a little longer and provide a single-product solution," he adds.

INSULATE AND AIR-TIGHTEN

The topic of insulation for roof systems is a growing concern for the green building community, which is frequently striving to meet new, strict energy codes and guidelines. In the recent *BD+C* roofing survey, leaks and failures were found to be the biggest concerns by far for Building Team members. Yet, good-quality insulation and well-specified air and vapor barriers are also significant priorities.

"Don't scrimp!" exclaims Stantec's Donovan on the subject of thermal and moisture protection. "Choose a high-quality system that can perform well under the full range of worst-case scenarios you can imagine for the roof."

Before determining which kinds of insulation and barrier products to select and specify, investigate how the livable space will ultimately be used, advises Michael Turcotte, owner of the design-build firm Turn Cycle Solutions (www.turncyclesolutions.com), Merrimack, N.H. For example, if the facility will be subjected to high moisture levels, as in a rehabilitation center, spa, or natatorium, the insulation system needs to incorporate some material, such as expanded polystyrene, which generally doesn't hold on to water.

"Moisture should be factored into every equation before building," says Turcotte. Consequently, Turn Cycle Solutions always begins a project by asking such questions as how many occupants the facility will host and what types of equipment services are likely to be included.

Targeting an insulation value of at least R-30 for the roofing system, Thibaudeau likes to go with polyisocyanurate insulation to ensure that the roof hits that goal. However, Ron Schwenger, a principal with the Vancouver-based building envelope consulting and design firm Architek (www.architek.ca), prefers rigid and batt insulation solutions for thermal performance. He is also optimistic about newer soy- and organics-based spray foam systems, as long as they can provide the same or better thermal efficiencies.

A proponent of rigid board insulation, Wesley Malone, LEED AP, a project estimator with Miami-based commercial roofing contractor Hartford South (www.hartfordsouth.com), relies on lightweight insulating concrete as well. "When a building has structural slope, rigid insulation is usually more cost effective, but when you have a building which requires the slope to be in the insulation, lightweight insulating concrete is usually the more economical choice," he explains.

Air/vapor barriers. While insulation is obviously vital to energy efficiency, the U.S. Department of Energy has issued reports showing that air infiltration and envelope moisture can dramatically reduce overall efficiencies. For that reason, when designing and installing a roofing-system, there are two other items that Turcotte's team focuses on very carefully: ventilation and proper air sealing.

"It's important to make sure there are no improper air changes happening between the conditioned and unconditioned spaces," cautions Turcotte. "If the roof is plagued by moisture from the conditioned space, the roofing system will never function properly."

Moshier emphasizes the importance of a continuous vapor barrier on the conditioned side of the roof plane, as well as properly detailed ventilation. "Air barriers are also important, especially in cold climates," he explains. "They must be placed carefully, evaluated for proper vapor permeability, and then be well specified, closely inspected, and tested. I recommend using a contractor approved by the American Air Barrier Association, or at least using their standards."

Shad Traylor, AIA, NCARB, LEED AP BD+C, a LEED administrator with the Melbourne, Fla.-based firm BRPH (www.brph.com), reports seeing an increase in the number of projects requiring air barriers to be tested after installation through commissioning. The project commissioning process is used to confirm the integrity of the wall and roof assemblies, Traylor points out. With this in mind, firms like BRPH show a preference for spray-foam insulation, because it can be used continuously for both the walls and the roof assemblies. This can minimize coordination issues among the involved trades when they are installing different air barrier systems, which must transition properly.

HOW TO KEEP A COOL TOP

Another important determination for the roofing system is whether a cool-roof coating or a lighter or darker surface material would significantly improve the building's energy use profile or its sustainability in general.

Building Teams should first reference the DOE's climate map to confirm the correct climate zone in which the project is located, advises Traylor, and then which design approaches are suitable for that zone. "Projects in climate zones 1-3 will probably benefit with a cool roof, as those southern, warmer regions necessitate roofs that reflect the sun's radiant heat to minimize heat gain," says Traylor, who has more than 23 years of experience in all phases of architectural design. "On the other hand, projects located in climate zones 4-7 might benefit from a darker roof material to absorb the heat."

Of course, running the energy equation is more complex than simply plotting a project on the map. To help Building Teams, the DOE offers a free cool-roof calculation tool on the Oak Ridge National Laboratory

website (http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm). "The software requires a few simple project inputs of your location, proposed roof, energy costs, and equipment efficiencies, and it outputs a detailed comparison between the proposed roof and a black roof to yield the annual energy savings," Traylor notes. "If the project is seeking LEED certification, understanding the solar reflectance index and roof slope parameters are also important."

Although cool roofs have been around for a number of years, some newer product choices have improved the possibility of achieving a good solar reflectance index (SRI) with various roofing types. According to the Portland Cement Association, SRI is a composite measure of a surface's solar reflectance and emittance. Emittance measures the surface's ability to let go of absorbed heat. For the LEED credit in "Sustainable Sites" for reducing a roof's potential heat-island effect, a point may be earned by designing a steep-sloped roof with an SRI of at least 29 or a low-slope roof with an SRI of 78 or better.

"Many companies are now offering cool-roof opportunities for their BUR or MB systems, and for those who prefer multiple plies or asphaltic-based materials, they can choose either a granulated cap sheet or a felt-back single-ply to achieve a cool roof," says Malone.

Some single-ply manufacturers are developing chlorine-free TPO roofing membranes with high reflectivity properties. "These newer olefin membranes use fiberglass or polyester for reinforcement, but achieve their elasticity through copolymers, as opposed to the plasticizers in PVC, which sometimes leach out and leave the material brittle," says Yanowitz,

However, plasticizer leaching in PVC takes years, and PVC roofs are known to last for decades.

As for existing roofs, white organic spray-applied membranes are becoming more popular, say some observers. "Most common among these are acrylic coatings, which are essentially thick, specially formulated paints that can be applied to many materials, including asphalt shingles, concrete tile, cedar shakes, some membranes, and painted metal," says Yanowitz. Specifiers and manufacturers alike advise that spray-on coatings should not serve as waterproofing, even though some products may be advertised as such. In general, Yanowitz advises his clients not to consider coatings as an alternative to other proven roofing practices.

One other innovative solution is a system which integrates the cool roof with a rooftop PV system. These systems qualify for state and federal grants under certain circumstances.

CAPTURING THE SUN'S POWER

The brightening appeal of photovoltaic (PV) rooftop systems relates to their ability to harness the sun's free energy for building use. There are also the newer, more affordable building-integrated systems and solar laminates and shingles that can be integrated directly into the roof surface. With a more competitive and established market of alternatives, PVs are becoming a viable option for increasing numbers of projects.

Introduced several years ago, some PV roofing laminates are bonded to flat steel pans with an adhesive backing, and can be applied onto existing roof surfaces. Shingles with thin-film solar cells incorporate PV properties directly into the shingle form, replacing conventional shingles.

PHOTO: COURTESY AMERESCO

The rooftop solar installation at Worcester State University, Worcester, Mass., which was delivered by solar contractor Ameresco, incorporates advanced Internet-enabled measurement and monitoring systems.

The beauty of BIPVs is that the products can replace or eliminate other building materials and systems. In addition, BIPV systems don't require ballast weight or roof penetrations for attaching solar arrays to the roof. On the other hand, BIPV systems may not be as efficient as flat PV modules in arrays mounted on a roof. "Flat panels, with solar tracking in one or two dimensions, harvest the maximum amount of renewable electricity, and new innovations using nanotechnology and molecular-scale materials are increasing the generating capacity of PV panels by utilizing a higher degree of indirect sunlight," reports Randy Pool, PE, LEED AP, a managing principal and mechanical engineer in Stantec's Winston-Salem, N.C., office.

Experts in PV system performance may recommend polysilicon panels to capture optimal efficiencies in converting sunlight to electricity per square foot of panel area, says Jim Walker, director of solar PV grid projects for energy-services company Ameresco (www.ameresco.com), Framingham, Mass. In terms of practicality, Moshier likes thin-film laminates, which have become more affordable and are easy to install. "They seem to work best on metal roofs, but I've been seeing more shingle, synthetic slate, and tile products on the market," he says.

Beyond the technology itself, PV roofing design remains a key part of the equation. "Building designers need to be involved so that the arrangement of solar panels on a building looks like it is part of the design, rather than just added on," says HGA's Thibaudeau.

When PV is added to existing roofs, thorough structural engineering and roofing evaluations are essential; for example, to assess the roof loading capacity or the condition of an existing membrane. The roof must be inspected for leaks and proper drainage, along with a general condition evaluation. Walker also points out that while older roofs built under previous building codes may allow for greater live and dead loads, current building codes enforce a higher safety factor for snow loading and drifting, which essentially reduces the available safety factor for PV panels. "Consequently, a structural engineer must be engaged early in the design process to provide PV system engineers with a roof drawing showing the code-acceptable areas of safe array placement," he says.

Another innovation in the roofing market is the "green-roof-ready" system, says CTL's Cook. Designed to accommodate PV or vegetated roofing systems that may not be included in the initial construction plans for the facility, the green-ready approach helps building owners spread the cost over a longer period of time by choosing to add on the PV or planted systems down the line, without voiding the roof warranty.

PLANTING A BETTER ROOF

Planted roofs are sprouting up with increasing frequency. In fact, this roofing category grew more than 16% in 2009 despite the economic downturn, according to Toronto-based Green Roofs for Healthy Cities.

RoofPoint: Roofing Industry's First Rating System

Now in its pilot phase, RoofPoint is set to be the industry's first comprehensive rating system for roof assemblies and projects. Spearheaded by the Center for Environmental Innovation in Roofing (www.roofingcenter.org), a Washington, D.C.-based nonprofit group founded by about 20 roofing product manufacturers and the National Roofing Contractors Association, the initiative seeks to fill the need for a rating system solely dedicated to sustainable roofing.

"Green building rating systems, with their predominant focus on new construction or major building renovation, tend to neglect the billions of square feet of reroofing systems installed on existing buildings every year," explains James Hoff, the center's director of research. "Furthermore, such systems may place too little emphasis on the durability and long-term performance required for a roofing system to be considered truly sustainable."

RoofPoint has been designed to evaluate roofing systems based upon five categories:

- Energy management
- Materials management
- Water management
- Durability and life cycle management
- Innovation

In addition, the program seeks to serve as a guideline for selecting energy-efficient, eco-friendly, and long-lasting roofing products. RoofPoint will also help owners and specifiers evaluate and compare system options, while working to acknowledge environmentally responsible roofing practices via certification.

Release of the first RoofPoint Certified Roofing Systems is targeted to wrap up by the summer. Currently available for public use, the document "RoofPoint Guideline for Environmentally Innovative Commercial Roofing" is accessible at: www.RoofingCenter.org.

RoofPoint Energy Management Credits

Credit	Title	Primary intent	Strategy
E1	High R roof systems	Reduce energy and GHGs	Increase roof system R-value
E2	Best thermal practices	Reduce energy and GHGs	Reduce thermal discontinuities
E3	Cool roof surface	Reduce energy, GHGs, and heat islands	Install climate-appropriate roof surface
E4	Roof air barrier	Reduce energy and GHGs	Install air barrier
E5	Rooftop energy systems	Produce clean energy	Install solar or wind energy-producing materials
E6	Roof daylighting	Produce clean energy	Install daylighting systems

Source: Center for Environmental Innovation

Energy management credits are one of five sections in the new RoofPoint rating system, developed by the Center for Environmental Innovation, now in pilot phase. RoofPoint also rates materials, water management, and durability/life cycle management.

PHOTO: COURTESY RAIMONDO DI EGIDIO/STANTEC

Modular planting trays were chosen for the green roof crowning Con Edison's Long Island City, N.Y., training facility.

"Nothing beats the cooling and heat-preservation effects of adding a vegetated roof to the building," says GreenWork's Copolla.

In terms of roofing systems compatible with vegetated coverings, standard go-to solutions include single-ply TPO and two-ply styrene-butadiene-styrene (SBS), as well as EPDM and PVC. "We find that fully adhered membranes are an excellent choice," says Architek's Schwenger. "Any leak problem is easy to locate because the water will not migrate."

With regard to the green roof component, Schwenger is a big fan of engineered, built-in-place systems: "These systems provide for long life cycle durability by protecting the membrane, and they utilize water-retaining drain board systems, which help to insure plant health and hence the life and durability of the entire green roof system."

Roof tray systems are another approach. They are modular, flexible,and easy to install. The planting trays arrive on the job site preplanted, and each tray can be specified with the desired depth based upon the plant species, according to Emily Andreae, a landscape architect in Stantec's Toronto office. "The practical side of this system is that you can easily lift portions of the trays out to repair any leaks in the waterproofing membranes. Roof drains, edging, and irrigation modules are also an option provided with the system," she says.

However, Schwenger points out that many newer roof tray systems have yet to be proven, and that Building Teams interested in a track record in terms of life cycle or durability may want to give them a closer look. He's not too excited about their plastic content levels and questions their water-retention capacity for mitigating stormwater issues.

Another determination to be made is whether to use an extensive or intensive planted systems. *Extensive systems* are thinner, with a media base of 1-6 inches, the most popular being about three inches. Extensive systems are also lighter and more affordable than intensive systems, and they are generally used as an ecological roof cover with limited roof access, explains Yanowitz.

"Due to the simpler construction and shallow system depth, extensive green roofs can be integrated onto pitched roofs, typically up to 30-degree slopes," he says. Plant choices include drought-, high heat-, and wind-tolerant species, he adds.

By contrast, *intensive systems* might be more accurately described as true rooftop gardens, with soil depths of greater than six inches that can incorporate more intricate, complex landscape designs. Often scenic, relaxing spaces with such novel features as vegetable gardens, recreation areas, and water features, intensive systems come with challenges but they also add value and usable amenity space to a property. Their installation and maintenance costs are greater than for extensive systems, and irrigation systems may also be required.

LIGHT FROM ABOVE

With the prominence of daylighting in sustainable design, no discussion of roofing systems would be complete without mention of skylights, roof windows, and glass space-frame construction. Although some Building Teams prefer not to deal with possible glare issues and the potentially increased HVAC loads associated with daylighting, newer products such as solar-tracking skylights and light tubes are making daylighting a more attractive option.

In addition to following the sun's path for greater daylight harvesting efficiencies, some skylight systems also integrate sensors, controls, and solar-powered shades for added savings. As for solar tubes, "They can be easily integrated into new designs or retrofitted into existing buildings at low cost and with considerable benefits, without significantly compromising thermal energy performance," says Yanowitz.

PHOTO COURTESY: OVERLAND PARTNER ARCHITECTS/PAUL MEYER

Two green roofs above the garages at the Horticulture Center at the University of Pennsylvania's Morris Arboretum, designed by Overland Partners Architects, are part of a larger rooftop strategy incorporating PV and a high-reflectance metal roof. Two types of planted roofs, intensive or extensive, are being used in green projects.

In terms of detailing solar tubes, skylights, roof windows, and similar penetrations systems with the roof material, Stantec's Donavan stresses the following points:

- Run the membrane or base flashing up well above the hazard line.
- Provide positive slope to drain, with pitches appropriate to the system.
- Locate joints where they can be readily inspected and repaired.
- Maintain continuity of the insulation material as it changes plane.

In addition, Yanowitz recommends maintaining continuity with the building air barrier system and thermal envelope. "Often it may be advisable to box in a solar tube installation or thicken the walls of a skylight platform shaft in order to increase the thermal insulation thickness so that these design features are not significantly weaker elements within the building envelope," he says.

As with all newer technologies and sustainability concepts, daylighting requires attention to detail as much as the desire to bring light and all its associated benefits into today's nonresidential facilities.

50 BILLION SF AND CLIMBING

The U.S. roofing market, which accounts for more than 50 billion sf of developed space, is offering more options for Building Teams than it ever has before. This means the potential for seeing some exciting changes in how buildings work to be greener, more energy efficient, and more comfortable and productive.

In fact, U.S. Secretary of Energy Steven Chu recently mandated the use of cool roofing for federal government facilities. If this order is any indication of new renovation and reroofing activity in the private sector, it seems the roof industry is well positioned to keep going green.

PHOTO: COURTESY GEORGIA-PACIFIC GYPSUM

Workers install a new roof on the Target Center, a Minneapolis entertainment arena, the fifth-largest extensive vegetative roof system in the U.S.

Editor's Note

This completes the required reading for this course. To earn 1.0 AIA/CES learning units, study the required reading and take the CEU test posted at www.bdcnetwork.com/SustainableRoofing.

SUSTAINABLE ROOFING EDUCATION MODULE

Pass this exam and earn 1.0 AIA/CES learning units! You must go to www.bdcnetwork.com/SustainableRoofing to take this exam!

1. According to the 2011 Building Design+Construction roofing survey, the two highest-ranking factors for roof system selection are:
   A. Reflectivity and recycled content
   B. Recycled content and durability
   C. Durability and energy efficiency
   D. Energy efficiency and reflectivity
2. Compared to BUR (built-up roofing), modified bitumen roofing materials offer which of the following qualities?
   A. Greater elasticity.
   B. Reduced off-gassing.
   C. Redundancy due to multiple-ply construction.
   D. All of the above.
3. True or false: Hot-melt application of built-up roofing (BUR) may release VOCs (volatile organic compounds) and particulates into the atmosphere.
   A. True.
   B. False.
4. According to the U.S. Department of Energy, which of the following roofing problems is likely to reduce the overall energy efficiency of a given building?
   A. Poor insulation performance.
   B. Air infiltration.
   C. Moisture within roof enclosure.
   D. All of the above.
5. Which roofing system can minimize structural roof-deck requirements due to its ability to span greater distances?
   A. Metal roofing.
   B. Single-ply membranes.
   C. Skylights and space frames.
   D. None of the above.
6. True or false: The solar reflectance index, or SRI, is a measure of a surface's solar reflectance only.
   A. True.
   B. False.
7. PV roofing laminates, which can be applied onto existing or new roof surfaces, consist of:
   A. BIPV films for application to skylights.
   B. Asphalt shingles with integrated solar cells.
   C. Self-adhering PV panels that attach to roof panels.
   D. None of the above.
8. A "green-roof-ready" roof system is designed to let building owners:
   A. Add a PV roof system later without voiding the roof warranty.
   B. Allow naturally occurring build-up of organic matter on roofs.
   C. Retrofit additional structural bracing for increased roof weights in later phases.
   D. Perform all of the above.
9. One important difference between intensive and extensive roof planting systems is that:
   A. Extensive planted roofs tend to allow for full roof access.
   B. Intensive planted roof systems are lighter than the extensive type.
   C. Extensive roof systems are typically less than six inches deep, while intensive planting may be deeper than six inches.
   D. Intensive roof systems are typically three inches deep, while extensive roof systems may be deeper than three inches.
10. Due to their simpler construction and shallow system depth, which of the following planted roof types can be integrated on to pitched roofs, typically up to 30-degree slopes?
   A. Large tree systems.
   B. Intensive green roof systems.
   C. Both extensive and intensive green roof systems.
   D. Extensive green roof systems.