Building owners know that their roof is a major investment spanning a long period of time. They also know that the return on their investment depends on a number of factors, including:

- Warranty
- Durability and service life
- Suitability for the building type and climate
- Design and construction
- Maintenance and repair requirements
- Life cycle costs (initial, maintenance, demolition/recycling/disposal, business disruption)
- Energy and environmental performance

A high return from a roof investment comes from optimizing all factors rather than focusing on only a few to the exclusion of others. For example, if primary importance is assigned to the choice of reflective versus nonreflective roofing, then insulation factors with a greater potential impact on performance and lifetime cost can be overlooked. Selecting a roof system is not a black or white decision.

Because a commercial roof is a system of interdependent components, owners should draw on technical expertise to assess a variety of factors. This report will focus on four considerations: 1) condensation risk, 2) insulation values, 3) energy and environmental performance, and 4) maintenance and service life.

Condensation Risk
We tend to think of roofs primarily as barriers to conditions outside of a building, but they are also barriers to conditions inside. This function has significant impacts for the life cycle costs of roofing systems.

For example, buildings with relatively high indoor moisture and large amounts of indoor air moving upward by the stack effect into the roof assembly may be especially prone to condensation. In turn, the condensation can produce wet and moldy roof insulation and deck, leading to costly and premature replacement, especially if a vapor barrier is not correctly specified and installed.

A paper by Manfred Kehrer, senior researcher at the Oak Ridge National Laboratory, and Simon Pallin, of the Chalmers University of Technology in Sweden, describes several factors that can increase the risk of condensation, including roof reflectivity and attachment method. Cool, reflective roofs absorb less sunlight than dark, nonreflective roofs. As a result, reflective roofs have a cooler temperature at night, increasing the possibility of nighttime condensation. The researchers found that a cool roof accumulates approximately twice the moisture below the surface membrane as a black surface.

In cold climates, reflective roofs with mechanical attachments may have an even higher risk of condensation. Penetrations can allow larger volumes of moist indoor air to intrude into the roof components under the membrane.

Kehrer and Pallin also cite research indicating that thermoplastic membranes (PVC, TPO) are prone to indoor air intrusion because the flexibility of the membrane allows a kind of billowing lift that increases the space where moisture can condense. Wind forces that create a fluttering effect, even on roofs properly sealed to the outside, can enlarge the space where moisture can condense under the membrane (see diagram below).

The researchers conclude that climate, solar radiation on the roof surface, indoor moisture levels, and indoor air intrusion should all be evaluated for their impact on condensation risk.

Insulation Values
Roof insulation plays a key role in energy efficiency, a fact reflected in codes and standards that have mandated increasingly higher minimum R-values for U.S. climate zones.
ASHRAE 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, has steadily increased insulation R-values for all U.S. climate zones through its 2004, 2007 and 2013 [to be published October 2013] editions (see charts). ASHRAE Standard 189.1, Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings, mandates R-values that are similar to the latest version of Standard 90.1. For many buildings, the insulation value has a greater impact on both energy efficiency and sustainability than the choice between a white roof or a black roof.

Despite insulation’s importance, minimum R-values alone do not ensure a given performance level due to the interdependent components in a system. For example, design and construction details have a direct impact on thermal performance. If thermal bridging occurs at insulation joints or at penetrations for mechanical roof attachments, the overall R-value can be less than the minimum required by code.

Building owners should also recognize that applying code R-values to insulation without assessing other system components will not lead to optimal performance.

“Insulation is a benefit in all climate zones and it works throughout the life of the roof,” says Diana Fisler, Ph.D., environmental construction platform leader for Johns Manville. “Before assessing the relative benefits of white and black roofs, building owners should ensure that insulation values are up to the code’s minimum or higher.”

Energy and Environmental Performance

Durability and service life are significant factors in environmental life cycle analysis. On one level, the service life will determine the period of time before the environmental impacts of demolition, disposal and replacement occur. For example, an average commercial roof is 300 squares (30,000 ft²) and ranges in weight from 100 pounds/square (single ply) to 700 pounds/square (bituminous, the greater weight of which usually corresponds to greater durability). Membrane removal sends anywhere from 15 to 100 tons of material to a landfill.

The materials used in the roofing system, its manufacture, and its transport also have environmental impacts. Finally, the roof has a variety of energy characteristics. The interaction of all these factors must be assessed in order to optimize roof performance.

The Evolution of ASHRAE Insulation Values

Above deck R-value by zone

To maximize efficiency and reduce energy costs, ASHRAE standards have steadily increased R-values for roof insulation in all U.S. climate zones.

ASHRAE 90.1 2013*
ASHRAE 189.1 2009
ASHRAE 90.1 2007/2010
ASHRAE 90.1 2004

*To be published October 2013

Data source: PIMA
Eight climate zones have been designated for determining ASHRAE-mandated R-values for roof insulation.

A new model developed by the nonprofit Center for Environmental Innovation in Roofing is an example of a tool designed to assess multiple factors. The RoofPoint Guideline uses energy credits as a basis for measuring a roof's impact on three outcomes:

1) Net energy savings (insulation, thermal bridges, air and vapor movement, and climate appropriateness)
2) Peak energy demand reduction (ability to reduce energy for air conditioning through cool roof strategies)
3) Renewable energy production (rooftop PV, skylights, daylighting).

Assessing net energy savings versus peak energy savings is important because roofs with the same thermal value but different reflectivity values will have different impacts on energy costs for space heating and cooling. In particular, the savings for cool roofs during periods of peak energy demand are comparatively constant across all climate zones. However, the net energy savings for cool roofs can decline quickly in cooler zones and even become negative, according to Fisler.

"Cool roofs have benefits in hot regions like climate zones 1 and 2, but the benefits diminish steadily in increasingly cooler zones," she says.

Although the performance of cool roofs in northern climates is usually predicted by models and calculations, there are also studies that have compared the real-world performance of reflective and nonreflective roofs in cooler climate zones. For example, a study done on identical buildings at a correctional facility in central New York state found no annual energy benefit associated with a reflective roof in zone 4.

**Maintenance and Service Life**

Subject to wind, rain, hail, snow, sleet and UV radiation, the roof may be the most vulnerable component of your building. Clearly, good maintenance and repair procedures have an impact on service life.

It is also important to recognize that the various components of the roof system require different maintenance procedures. For example, insulation in a weather-tight roof system should require no maintenance.

"It is good practice to bring the roof insulation up to current code, which can be done by leaving the old, undamaged insulation in place and adding more layers of polyiso," says Amy Ferryman, Ph.D., sustainability scientist for Johns Manville.

In order to maximize a roof system’s service life, non-roof maintenance must also be considered. For example, window washing and HVAC maintenance involve foot traffic that can be more damaging to a roof membrane than weathering. White roofs that require cleaning to maintain their reflectivity will also increase foot traffic, Ferryman notes.

Building owners should ensure that suppliers
include walkways or pavers as necessary to protect the roof. Suppliers should also provide information about maintenance requirements for all system components.

**Conclusion**

The greatest return on a roofing investment comes from optimizing the interaction of system components for a given building and climate zone. Because there is no single solution, the roofing industry offers many choices—including white, black, single ply and bituminous systems.

When making a decision on roofing, building owners should ensure that their suppliers have the necessary technical expertise to assess the component interactions that determine service life, sustainability, and life cycle cost. Owners should also ensure that their system is designed by a certified roofing designer or architect and installed by a qualified roofing contractor.

Amy Ferryman joined Johns Manville in 2002, after receiving her Ph.D. in analytical chemistry from Kent State University in Kent, Ohio. During the first five years of her career at JM, she provided expertise in the areas of microscopy and surface science, and managed these laboratories. In 2009 her focus changed to the area of sustainability, in which she has led programs to reduce the environmental impacts of JM products and processes, plus assisted with educating colleagues and customers on topics related to sustainability. In November 2012, Amy returned to the laboratory setting as manager of the Product Testing Laboratories at the Johns Manville Technical Center in Littleton, Colo. She continues to focus on projects related to sustainability, which includes leading JM’s corporate-wide life cycle assessment (LCA) program.

Diana Fisler received her bachelor’s degrees in physics and geology at the University of Massachusetts, and then combined these two areas of study with a Ph.D. in geophysics from Pennsylvania State University. She joined Johns Manville in 1998 as a glass chemist, developing new glass chemistries for improved production efficiency. She researched new binders for fiber glass and led the JM product testing laboratories before assuming her current position as Platform Leader in Environmental Construction. In this position she and her team are responsible for using building science to deliver new technologies for controlling heat, moisture and air flow through the building envelope.

**REFERENCES**

