BEYOND ENERGY SAVINGS:

The Long-Term Benefits of LEED®-Compliant Buildings

By Tom Bauer and Frank Percaciante

The standards defined by the United States Green Building Council (USGBC) regarding environmentally responsible products are catalyzing the rapid proliferation of highly reflective roof surfacing systems in North America. As this trend continues, design professionals, building owners, and facility managers will need to analyze product claims in an objective and consistent manner in order to evaluate the long-term cost-to-value benefits of reflectivity and other sustainable performance characteristics. This article explains the various aspects of roof design that may contribute to LEED®[1] buildings' performance and explores the ways in which initial reflectance affects the long-term weathering performance of reflective systems, thereby extending their cost-to-value benefits beyond the most obvious and immediate benefit of saving energy.

ROOF SYSTEM DESIGN

Designing a roofing system that focuses on sustainability, long-term performance, and continued energy enhancement for improved life-cycle costing requires a multi-phased process:

- The first phase is to identify the proper roofing components to meet or exceed the minimum requirements contained in the specification.
- The second phase is to identify the expected service life and extrapolate from it the total cost of ownership.
- The final phase is to develop a customized, performance-based specification that takes into account the desired system longevity, defining the specific roof-component performance requirements necessary for achieving an established sustainable design criteria.

When we look at a typical roofing system, each of the components shown in *Figure 1* offers opportunities for specifying high levels of product performance.

Although each individual component has the potential to contribute to overall sustainable performance, the major contributor to USGBC's LEED® buildings' criteria is the surfacing of the roof system. In addition to potentially contributing valuable LEED® points, the surfacing of the roofing system provides the primary membrane protection against ultraviolet (UV) radiation, temperature variations, and weather exposure. The remaining components typically provide the strength, waterproofing protection, and energy performance for the roofing system, while offering the potential for other sustainability attributes such as the conservation of natural resources.

COOL ROOF COATING REGULATION

As designers consider specifying reflective roof surfaces, there are two resources providing objective, third-party testing:

- The Cool Roof Rating Council (CRRC) is an independent and non-biased organization that has established a rating system for displaying accurate radiative property data on the outermost layer of roof surfaces. The core of the CRRC is its Product Rating Program, through which roofing product manufacturers can label their products with solar reflectance and thermal emittance values as measured by the CRRC Accredited Independent Testing Laboratories.
- The EnergyStar®[2] program was developed by a joint effort between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). The EPA and DOE joined forces to develop the EnergyStar® program due to the fact that the majority of electricity is gen-

erated by burning fossil fuels, which create air pollution. Reducing the amount of energy needed to cool buildings has a direct effect on the reduction of air pollutants.

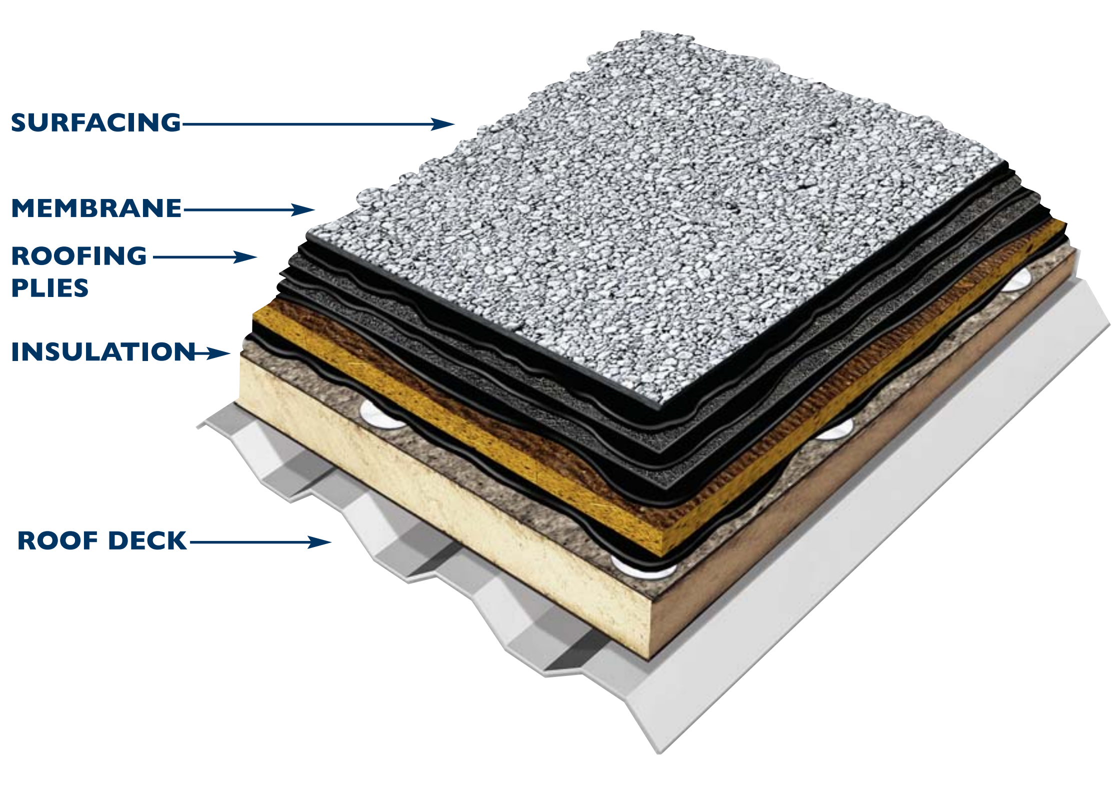

Figure 1 – From top to bottom, the components of a typical roof system are the surfacing, the membrane, the plies, the insulation, and the underlying roof deck.

Included in the EnergyStar® program is Version 2.0, Specification for Roof Products. The specification outlines the performance and testing requirements that roof products must meet in order to earn EnergyStar® qualification. The EPA's EnergyStar® Roof Product Program has cool roofing specifications for both low-sloped and steep-sloped roofs. Low-sloped roofs (those below 2:12) and flat roofs must have an average initial albedo of at least 0.65, and steep-sloped roofs must have an average initial albedo of 0.25 or more. (Albedo represents the fraction of incident electromagnetic radiation that is reflected by the roof's surface, with the higher reflectivity values measuring close to 1.0 and the lowest measuring close to zero.)

Although the USGBC does not evaluate roofing products, it promotes the use of reflective surfacing through the widely known credit for the reduction of urban heat island effect. The intent, according to LEED®, is to "reduce heat islands [thermal gradient differences between developed and undeveloped areas] to minimize impact on microclimate and human and wildlife habitat."

According to the USGBC, urban areas produce the urban heat island effect through their extensive use of dark, heat-absorbing roofs. The temperatures in the air above heat islands and their heat-absorbing roofs can be as much as 12˚F hotter than the surrounding suburbs, leading to higher air conditioning costs, greater use of electricity, and discernable, unhealthy levels of smog and ozone.

For low-sloped roofs, the USGBC has adopted requirements of a solar reflectance index (SRI) of 78. For steep-sloped roofs, the SRI requirement is 29 in order for the roof to contribute LEED® points. To qualify for the point, the following options are available in USGBC NC v2.2:

- Use roofing materials having an SRI equal to or greater than the values outlined in the requirements for a minimum of 75% of the roof surface.
- Install a vegetated roof for at least 50% of the roof area.
- Install high-albedo and vegetated roof surfaces that in combination meet the criteria below. (See *Equation 1*.)

UNDERSTANDING SRI

Regardless of the kind of material used, cool roofs have two important surface properties: a high solar reflectance and a high thermal emittance. Solar reflectance (also called albedo) is a measure of the ability of a surface material to reflect sunlight. Thermal emittance is defined as the percentage of energy a material can radiate away after it is absorbed. It is the ability to release absorbed heat. Scientists use a number between 0 and 1 (or a percentage) to express emittance.

Solar reflectance and thermal emittance have noticeable effects on temperature. Some conventional roof surfaces have low reflectance (from 5% to 25%) and high thermal emittance (typically over 80%). These surfaces can heat up to as high as 190°F (88˚C) at midday during the summer, while cool roofs with both high reflectance and high emittance warm to only 120˚F (49˚C) in the summer sun.

To calculate the SRI for a given material, it is necessary to obtain the reflectance and emittance values for the material:

- SRI is calculated according to ASTM E1980. This is a standard practice for calculating the SRI of horizontal and low-sloped opaque surfaces with emissivity greater than 0.1. Reflectance is calculated according to any one of three ASTM standards: ASTM E903, ASTM E1918, or ASTM C1549.

(Area of SRI Roof / 0.75) + (Area of Vegetated Roof / 0.5) ≥ Total Roof Area

Equation 1

- Emittance is calculated according to ASTM E408 or ASTM C1371.

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CALCULATING ENERGY SAVINGS

There are a variety of tools available on the Web to estimate the cost savings of different insulation and membrane-surfacing specifications. These tools evaluate the annual cost-savings based on a specified roofing system in order to help one identify long-term return on investment (ROI), thereby justifying any initial capital expenses associated with increased energy performance. The following calculators are listed based on complexity and the amount of information required to provide saving estimates, from least to most complex:

- The EnergyStar® Roof-Comparison Calculator (**www.roofcalc.com**) estimates annual energy savings for typical building types with non-metallic-surfaced roofs using typical weather conditions. These estimates are derived based on simulations run with the DOE-2.1E model using cooling and heating degree-days.
- The DOE's Cool-Roof Calculator was developed at the agency's Oak Ridge National Laboratory. The calculations require more input data, and there are 243 different locations built into the pull-down lists in the calculator. There are two versions, built around different facility sizes:
  - — For large facilities, Version 2.0, at **www.ornl.gov/sci/roofs%2Bwalls/facts/CoolCalcPeak.htm**
  - — For small and medium-sized facilities, Version 1.2, at **www.ornl.gov/sci/roofs%2Bwalls/facts/CoolCalcEnergy.htm**

In addition to the above energy calculators, many trade associations, such as the National Roofing Contractors Association (NRCA), have their own online calculators to help in the specification and design of an energy-efficient roofing system. It should be kept in mind that actual energy savings will vary, based on such factors as building design, building operation, cooling and heating equipment, and local weather, regardless of the calculator used.

One factor that is not easily accounted for by any calculator is the tendency for normal wear and environmental conditions to degrade the reflectivity of low-sloped roof system surfacings over time. Such reductions can be attributed to the fact that low-sloped roofing systems have a tendency to accumulate more dirt and debris, since their slope is not great enough to allow dirt removal from rain runoff.

In order for the actual energy savings from reflectivity to be sustained over time, it is important to follow the maintenance procedures specified by the roofing manufacturer. Proper maintenance minimizes degradation of the surfacing and maximizes energy savings, resulting in excellent building protection that will realize the life-cycle savings potential inherent in reflective solutions.

SURFACING AND LONG-TERM PERFORMANCE

Current emphasis on energy efficiency and conservation has led some energy codes to specify minimum solar reflectance values for roofing systems. In addition to providing geographically based energy savings, reflective coatings protect roof systems from the effects of UV and weather exposure and may be the single best tool for extending the working life of a roof.[3]

Reflective coatings can also provide increased fire resistance and impact resistance, aesthetic enhancement, reduced maintenance costs, and improved roof-system thermal performance.

To help understand these and other additional benefits of reflective coatings, the Midwest Roofing Contractors Association (MRCA) conducted a research program to study the performance attributes of liquid-applied roof coatings. In the study, six full-scale test roofs were coated and exposed to the weather in four different climatic regions of the United States. This study verified the impact of reflective coatings in regard to their ability to reduce the effects of ultraviolet rays and weather exposure on roofing systems.

Test systems included commodity-grade, polyester-reinforced SBS and APP polymer-modified asphalt membranes that typically undergo minor post-application shrinkage. Key findings included:

- Membranes coated with white acrylic coating were found to be without stress cracks or shrinkage of the coating over the end laps of the membrane. The white acrylics appeared to moderate the thermal movements within the tested membranes, thereby minimizing the effects of post-application, thermally induced shrinkage of the polyester-reinforced membranes. This finding provides reason to believe that the white acrylics moderate thermal movement in modified roofing membranes, thereby reducing the amount of thermal variances and stresses, preventing shrinkage and membrane degradation.
- All of the coatings in the test systems provided weather-shielding benefits for the underlying membranes by protecting the membrane from the adverse effects of direct exposure to sun and weather. This finding was verified by carefully removing small locations of the coating from membrane areas, then closely examining and comparing the once-coated membrane surface with the uncoated, exposed, and weathered surface of the control areas.

The study also verified the impact of reflective coatings and the importance of identifying factors that deteriorate roofing systems. In simple terms, the study demonstrated that the hotter the roof gets, the faster it wears out. It was found that today's energy-conscious policies, including the trend towards increased building insulation, may actually be preventing solar heat from dissipating through roof decks and into the building if the roof's surface is dark. When the system is unable to transfer heat, heat gain builds up within the roofing membrane, accelerating the degradation process.

CRITICAL FACTORS IN EVALUATING LIFE-CYCLE COSTS

A life-cycle cost analysis is a methodology for comparing multiple investment options for their financial merit over a specified investment horizon. A cost-to-benefit comparison is an analysis of an investment that does not yield a return but provides an associated benefit over an anticipated period of time as a result of the costs that are incurred by the investor. For roofing assets, the cost is usually the expense of the initial installation plus its yearly maintenance costs. The benefits are leak-free performance and uninterrupted use of the facility due to the absence of roof leaks. The goal of such an analysis is to maximize the longevity of the leak-free benefit for the lowest possible total cost of ownership.

Since different roofing systems have different initial costs, maintenance requirements, and performance expectations, the comparison can be examined on the basis of net present value (NPV). An NPV analysis incorporates the total direct costs associated with an investment as a function of when they are incurred versus the required rate of return for the investor. The NPV is calculated to adjust each expected expense to present value (that is, to the cost today of any anticipated future costs). The result of the NPV analysis is generally recognized to be a representative model for the total cost of ownership of one roofing option versus another. Once the result is determined, the investor will most likely choose the option that yields the total lowest cost for the expected benefit.

To fully understand the impact of reflective roof coatings on the total costs of ownership, a life-cycle cost analysis should be used to draw fair comparisons between multiple options. For the purposes of discussion, let's analyze and compare the life-cycle savings potentials of these systems:[4]

- A modified roof with mineral surfacing
- A modified roof with a flood coat and gravel surfacing
- A modified roof with a polyvinylidene flouride (PVDF) reflective coating applied at the time of installation
- A modified roof with a PVDF reflective coating applied at the time of installation and an additional PVDF restorative coating applied after ten years

Here are the assumptions incorporated into our life-cycle cost analysis:

- **Weighted Average Cost of Capital (WACC)** is the required rate of ROI for a company, based upon the expectations of the industry and the individual company's shareholders. For this analysis, we assumed the WACC to be 9.18%, which is a fair anticipated ROI for most manufacturing companies. A company with a WACC of 9.18% would expect an investment of $1,000 today to be worth $1,091.80 a year from now. Conversely, $1,091.80 a year from now is worth $1,000 today.
- **Roofing Materials Inflation Rate**, for the purposes of our analysis, is compounded at a rate of 6% each year. This is used to adjust the roofing materials portion of the expenses to what they are expected to cost in the future. The inflation rate of 6% is a combination of the generally accepted 3% standard inflation rate and an additional premium of 3% to account for the expected volatility associated with the oil and energy markets over the next 40 years. Experience has shown that it is reasonable to assume that roofing materials account for about 40% of the total cost of a project or preventive maintenance; therefore, the roofing materials inflation rate is applied to 40% of these costs.
- **Installation Labor Inflation Rate** is compounded at a rate of 4.5%, year after year, to adjust the roofing labor portion of the project or maintenance expenses to what the labor is anticipated to cost in the future. The inflation rate of 4.5% is a combination of the generally accepted 3% standard inflation rate and an additional premium of 1.5%. Experience has shown that it is reasonable to assume that labor will account for about 60% of the total cost of a project or preventive maintenance; therefore, the labor inflation rate is applied to 60% of these costs.
- **Maintenance Costs** are composed of three parts:
  - — **General Housekeeping and Visual Inspection** is calculated at 3.9 cents per sq ft per year, a cost that remains constant for all roof finishing options.
  - — **Minor Membrane and Surface Repairs** are calculated at[5]:
    - ◊ 1.6 cents per sq ft for flood- and gravel-surfaced roofs
    - ◊ 1.0 cents per sq ft for PVDF-coated roof surfaces throughout the coating's

anticipated lifespan of ten years, reverting to 1.6 cents per sq ft afterward, as the PVDF coating degrades

— **Flashing Repairs** are calculated at 3.3 cents per sq ft per year. As the portion of the roof most likely to fail, flashings may experience splits, tears, and voids that require repair or complete replacement at some point during the analysis horizon to ensure proper performance. This cost remains constant for all roof finishing options.

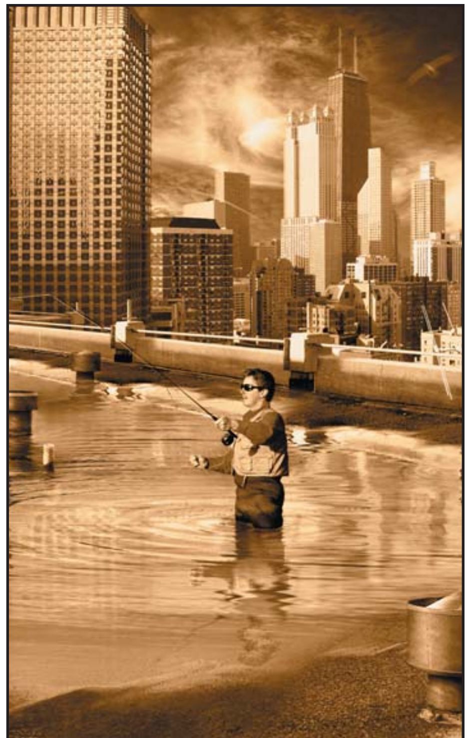
- **Depreciation and Tax Benefits** of roofing assets are based on a 39.5-year, straight-line depreciation method. The depreciation tax savings is calculated by utilizing the highest federal corporation income tax rate, 36.5%, and an average state income tax rate, 6.0%. The tax savings applied to the maintenance expenses use these same income tax rates.
- **Roof System Life** assumes a 20-year lifespan for a modified membrane. If the modified membrane is finished with a flood coat and gravel, then a 25-year warranted lifespan is assumed. The reflective coating used for this analysis was a highly reflective PVDF coating that may be assumed to last at least as long as the 10 years it is warranted for, since these coatings differ from tried-and-proven acrylic coatings only in their polyvinylidene fluoride content. When this resin has been substituted for traditional acrylic technology in other construction materials, it has resulted in superior longevity in comparison to earlier generation acrylics. It is assumed that the roof system will remain intact at the end of the coating's warranted life. The underlying roof system should then begin to degrade as normal.
- **Analysis Period** used for this comparison was 40 years, which is the longest expected performance life for a modified roof with a PVDF reflective coating applied at the time of installation, and an additional PVDF restorative coating applied after 10 years. The other two roofing options (a modified roof with a flood-and-gravel surfacing and a modified roof with a PVDF reflective coating applied at the time of installation) were evaluated and compared fairly to the 40-year option using the method of equivalent annual cost (EAC). EAC takes all of the costs associated with an additional roof replacement over its entire lifespan and adds them up to create an annuity. The EAC annuity is then applied to the analysis for the years necessary to draw a fair comparison. This method ensures that a roofing option that has a serviceable life beyond the analysis period does not get penalized for costs associated with those additional years of service or for the entire cost of new roof replacement.

RESEARCH RESULTS

In order to make certain that the life-cycle analysis included all of the direct costs and benefits associated with each roofing option, the roofs' energy-saving potentials were evaluated using the NRCA's Energywise Roof Calculator, with Buffalo, NY, as the sample location. The results of the Energywise calculations were inconclusive. There was no significant net energy cost savings realized from applying a highly reflective and emissive coating in Buffalo, NY. Therefore, the application of the coating was evaluated in the life-cycle-cost program exclusively on the basis of its initial cost, expected maintenance, and anticipated longevity.

Each of the roof systems was evaluated over a 40-year investment horizon. The life-cycle analysis demonstrated the value of coating a roof in comparison with noncoated roofs and flood-and-gravel roof systems. That value was exclusively derived from extending the roof system life and reducing the maintenance required to keep the roofs performing leak-free. The benefits of coating were demonstrated in both initially coating a roof for surfacing and in reapplying the coating throughout the roof's lifespan. Specifically:

- The mineral-surfaced roof system was calculated to have a present value of $18.68 per sq ft for 40 years of performance.
- The roof system with a PVDF reflective coating applied at the time of installation was calculated to have a present value of $18.19 per sq ft.
- The roof system with a PVDF reflective coating applied at the time of



installation and an additional PVDF restorative coating after 10 years was calculated to have a present value of $16.17 per sq ft.

These results are summarized in *Figure 2*.

When the PVDF-coated roofs were compared to a flood-and-gravel-surfaced roof, the results clearly showed there is value in continually coating a roof throughout the roof's lifespan versus allowing a flood-and-gravel roof system to degrade. Specifically:

- The flood-and-gravel-surfaced roof system was calculated to have a present value of $17.19 per sq ft for 40 years of performance.
- The roof system with a PVDF reflective coating applied at the time of installation was calculated to have a present value of $18.19 per sq ft.
- The roof system with a PVDF reflective coating applied at the time of installation and an additional PVDF restorative coating after 10 years was calculated to have a present value of $16.17 per sq ft.

These results are summarized in *Figure 3*.

CONCLUSIONS

Whether the driving force behind selecting a reflective coating is obtaining LEED® points, following USGBC requirements, and/or environmental conscientiousness, there are many benefits, both tangible and intangible, that justify the initial expense. A thoughtful life-cycle cost analysis demonstrates that the application of a highly reflective PVDF coating, in comparison with a flood-and-gravel or mineral-surfaced roof, is financially and environmentally beneficial — even when the net energy savings is negligible.

Some of the tangible, ROI benefits associated with the installation of a PVDF highly reflective coating are:

- Reduced membrane-surface maintenance
- Extended working life of a roof
- Lower extreme temperature exposure
- Smaller intraday temperature fluctuations
- Reduced UV exposure and degradation
- Added weather shielding
- Reduced membrane degradation

Some of the less tangible but highly desirable benefits of a PVDF reflective roof

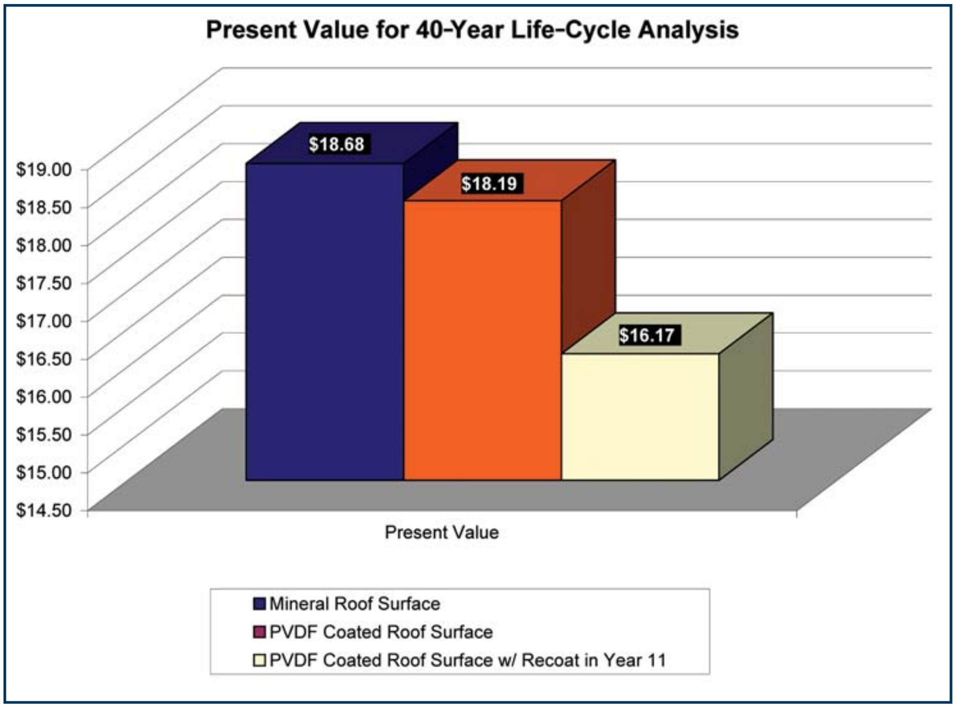


Figure 2 – The values of variously surfaced roofs ranged from $18.68 for mineral surfaces, to $18.19 for PVDF-coated surfaces where the coating was applied at the time of installation, to $16.17 for PVDF-coated surfaces where an additional restorative coating was installed at year 10 of the roof's life.

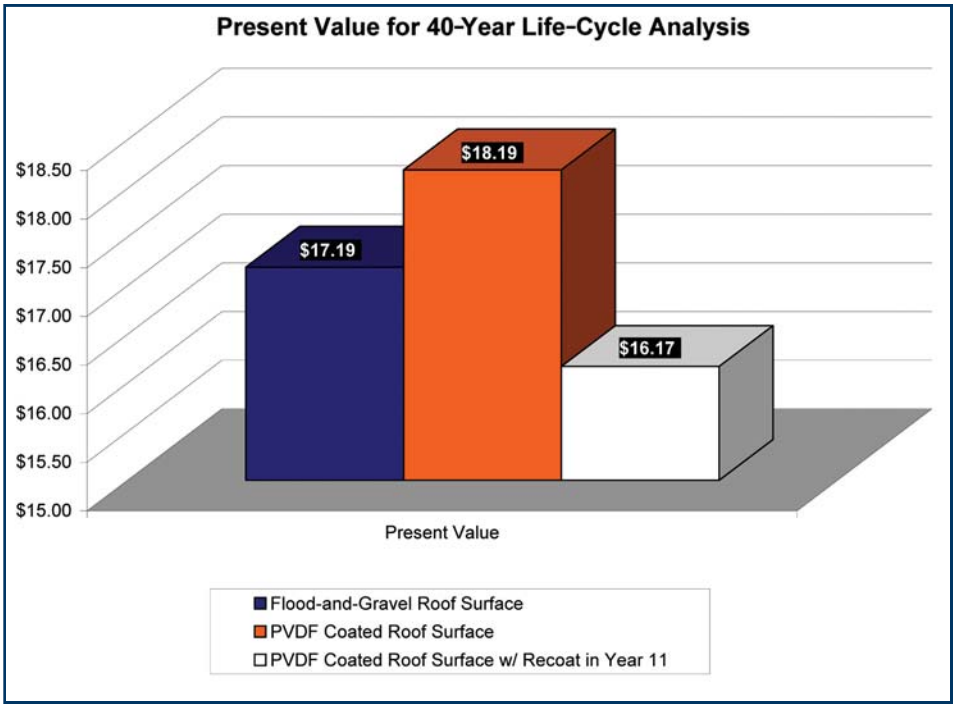


Figure 3 – The values of variously surfaced roofs ranged from $17.19 for flood-and-gravel surfaces, to $18.19 for PVDF-coated surfaces where the coating was applied at the time of installation, to $16.17 for PVDF-coated surfaces where an additional restorative coating was installed at year 10 of the roof's life.

coating are:

- The reduction of the heat island effect in urban areas
- Environmental conservation due to postponement of complete tear-off and replacement
- Achievement of LEED® certification points

Ironically, analysis demonstrates that reflectivity, although frequently chosen for less tangible benefits, inevitably achieves quantifiable long-term financial benefits, even in the absence of net energy consumption savings.

REFERENCES

1. LEED® building performance refers to the Leadership in Energy and Environmental Design® (LEED®) Green Building Rating System®, which is a voluntary, consensus-building national standard that was initiated by the U.S. Green Building Council (USGBC) for developing high-performance, sustainable buildings.
2. ENERGYSTAR® is a registered trademark of the U.S. government. The ENERGYSTAR® program represents a voluntary partnership between businesses and organizations and the federal government to promote energy efficiency and environmental activities.
3. R. Antrim *et al.*, "The Effects of Acrylic Maintenance Coatings on Reducing Weathering Deterioration of Asphaltic Roofing Materials," *Roofing Research and Standards Development*, 3rd Volume, ASTM STP1224; and C. Boutwell *et al.*, "Building for the Future: An Energy Study in Roofing," University of Southern Mississippi.
4. W. Kirn, "Life-Cycle Cost Effects of Roof Coatings," *Interface*, RCI, Inc., April 1998.
5. Numbers associated with this model are based on the premise that a coated membrane needs minimal preparation for additional resurfacing, versus a flood coat; that is, it is assumed that an aggregate-surfaced system would require intensive preparation prior to resurfacing, including, but not limited to, aggregate removal.

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Frank Percaciante is the divisional controller for Design-Build Solutions, Inc., a Garland Industries subsidiary. In that role, he is responsible for conducting the financial analyses and developing the scopes of work for construction contracts. Percaciante has designed and optimized mathematic tools that analyze the life-cycle cost-to-value benefits of various building components and roofing systems. The proprietary life-cycle costing tool used in this article's analysis was developed by Percaciante in collaboration with John Carroll University (JCU) economics professor Dr. Scott Moore, who specializes in asset pricing. Percaciante has worked in the roofing industry for 10 years. He majored in finance, with a minor in economics, at JCU in Cleveland, Ohio.