CONSULTANT/CONTRACTOR ADVOCACY FOR ENERGY AND ENVIRONMENTAL CONSERVATION

BY THOMAS L. SMITH, AIA, RRC AND DREW GAGLIANO

Introduction

The dramatic increase in the cost of gasoline in the first half of this year brings back painful memories of the 1973 Energy Crisis. Before the oil embargo, petroleum products were plentiful and cheap, and nuclear power plants were favorably viewed. There was little incentive to conserve energy. Automobiles were large, they were not fuel efficient, and they emitted a considerable amount of pollution. Many low-slope roofs were not insulated, and those that were typically only had 3/4″ to 1-1/2″ of traditional, low R-value insulation. In South Central Alaska, the typical low-slope roof had 3″ of perlite (R-value of 8.34).

The oil embargo resulted in long lines at gas stations, with waiting times of an hour or more. Building owners soon began to experience significant increases in their heating and cooling costs. With the sharp rise in operational expenses, owners started demanding more energy-efficient buildings. They realized the economic wisdom of paying for more insulation in order to decrease their monthly heating and cooling bills. Almost overnight, the typical R-value for low- and steep-slope roofs doubled or tripled. Prior to this era, plastic foam roof insulation had a minor market share, but the embargo permanently changed that.

Significant advances were made over the next ten years, both in automobile fuel efficiency and energy efficient roofs. Alternative energy sources such as solar and wind also experienced growth and development. However, with the collapse of the price of oil in 1985 and lack of support for alternative energy sources at the federal level, the concern about energy efficiency waned. Unfortunately, many buildings have been built and reroofed since that time with inadequate attention to conservation. With our nation's lack of attention to energy conservation, we are now more dependent upon imported oil than we were in 1973. In the late 1970s the Alaskan pipeline began delivering the vast oil reserves of the North Slope, but that new source has been greatly exceeded by our demand.

With this perspective, and the fact that in the U.S., building operations consume about 40% of the total energy used, roof consultants and contractors should be advocates of energy efficient roofs. In addition to energy conservation, the roof can also have environmental consequences in urban areas. This article provides information to help consultants and contractors to become conservation advocates.

The Basics

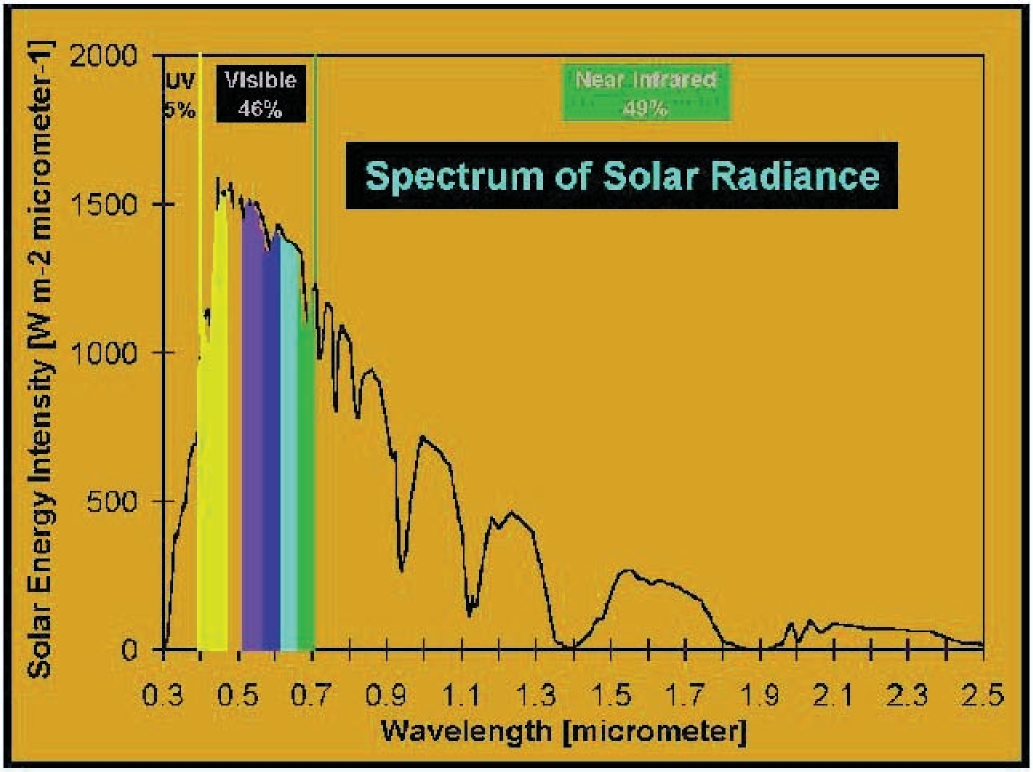
On buildings that have very large roof areas compared to wall areas, the thermal performance of the roof assembly is typically the dominant factor in the amount of energy consumed for heating and/or cooling the building. The thermal performance of the roof assembly is a function of the U-value of the assembly (which is primarily governed by the total R-value of the insulation), the mass of the assembly, and the reflectivity of the roof surface. The *NRCA Roofing and Waterproofing Manual* and The *NRCA Energy Manual* (which is included in The *NRCA Roofing and Waterproofing Manual*) provide in-depth discussion on the basics of heat transfer and heat flow calculations.

There are diminishing returns on the insulation investment. At some point, adding more insulation will not be cost effective. The optimum amount of insulation is primarily a function of the winter or summer ambient temperature, the design service life of the roof system, and the present and projected cost of energy. In hot climates, roof reflectivity can also influence the optimum amount of insulation. NRCA's computer program, *RoofWise: The Digital Energy Workbench*, can be used to determine the optimum thermal resistance. However, it does not consider roof surface reflectivity.

Thermal bridges decrease the efficiency of the insulation system. Thermal bridges occur at mechanical fasteners that are used to attach the insulation or membrane. Metal fasteners with metal plates promote the greatest heat transfer. The effects of this type of bridging can be minimized by mechanically attaching the first layer of insulation and adhering a second layer above it. There are no effective ways to minimize thermal bridging of mechanically-attached membranes, other than specifying a fastener that is less prone to heat transfer. Thermal bridges also are created by the joints between boards. Therefore, larger boards are more efficient than smaller boards. However, depending upon system configuration, it may be prudent to specify a smaller board because of other roofing considerations (e.g., in a hot-applied application, a 4′x4′ board is preferable to a 4′x8′ board because of attachment concerns). Specifying at least two layers of insulation is recommended to minimize the influence of board joints.

Few designers consider the relatively significant thermal reductions associated with fasteners or board joints, and these issues are not accounted for in *RoofWise*. Reference 1 provides information on calculating the influence of fasteners, and

Figure 1



Source: Oakridge National Laboratory (ORNL)

Reference 2 provides information on board joint calculations.

Thermal drift (aging): HCFC-blown plastic foam insulations (polyisocyanurate and extruded expanded polystyrene) lose R-value over time, as air diffuses into the foam's cells and the blowing agent diffuses out. The R-value that polyisocyanurate insulation offers over the life of the roof is substantially below the value typically advertised. The advertised value is usually based on testing after six months of exposure to prescribed conditions. Reported R-values are often in excess of 7 for a one-inch product, whereas NRCA recommends using an aged R-value of 5.6 per inch thickness. The manufacturers have developed new techniques for assessing in-service R-value, but, unfortunately, they have not implemented the new method. Designers should use an in-service R-value rather than the 6-month value.

After selecting the desired R-value for the insulation system and the system configuration (i.e., the number of layers and the type and thickness of insulation in each layer), it is necessary to consider whether or not a vapor retarder is needed. The *NRCA Roofing and Waterproofing Manual* provides information on moisture flow, vapor retarders, and calculation of the dew point temperature. With *RoofWise* it is quick and easy to calculate the dew point temperature and to confirm that the retarder is properly located. The last edition of the *Manual* provided a new methodology to assess the need for a retarder in high humidity buildings in warm climates.

The most recent and sophisticated method for determining the need for a vapor retarder has been developed by the Oak Ridge National Laboratory (ORNL). In addition to considering interior humidity and temperature and outdoor temperature, it considers roof surface reflectance and moisture absorption properties of the roof insulation and deck. To use this web-based calculation procedure, go to www.ornl.gov/roofs+walls/ and click "interactive calculators," then click "moisture control in low-slope roofing." For further information on this procedure, see Reference 3.

Thermal mass: Thermal mass can be provided by a heavy roof covering, such as aggregate or paver ballast or concrete tiles, or by a concrete roof deck. With a heavy roof covering, heat energy is stored in the ballast or tiles. Late in the afternoon, the massive covering becomes sufficiently warm to transfer heat to the remainder of the roof system. Cooler late afternoon or evening ambient temperature cools the covering so that not all of the stored heat is transferred to the building's interior. A concrete deck behaves similarly. However, if the building is occupied in the evening, caution is urged. The hot slab acts as a radiant heater, which can make conditions quite uncomfortable. To avoid this problem, thermal insulation can be provided below the slab, or a substantial amount of insulation can be provided above the slab. In warm climates where heating is not an issue, a highly reflective membrane directly over the slab (i.e., no insulation), can be a very efficient system. The reflective membrane minimizes the amount of heat energy transferred to the deck (as discussed in the following section), and the mass of the slab retards heat flow into the building until the cooler hours of the day. Unfortunately, there are no quantitative design guides available to designers who desire to incorporate thermal mass design strategies.

Reflectivity

Reflectivity refers to the ability of the roof's surface to reflect solar energy. The greater the reflectivity, the cooler the roof surface, which results in lower air-conditioning demand. To understand the importance of a roof surface's reflective properties, one must first understand the spectrum of solar radiance. In general, the spectrum of solar radiance ranges in wavelength from 0.3 to 2.5 micrometers. As *Figure 1* shows, approximately 46 percent of the spectrum of solar radiance is visible light. The remaining portion of the spectrum is non-visible with approximately 49 percent in the near infrared and five percent in the ultraviolet (UV) portions.

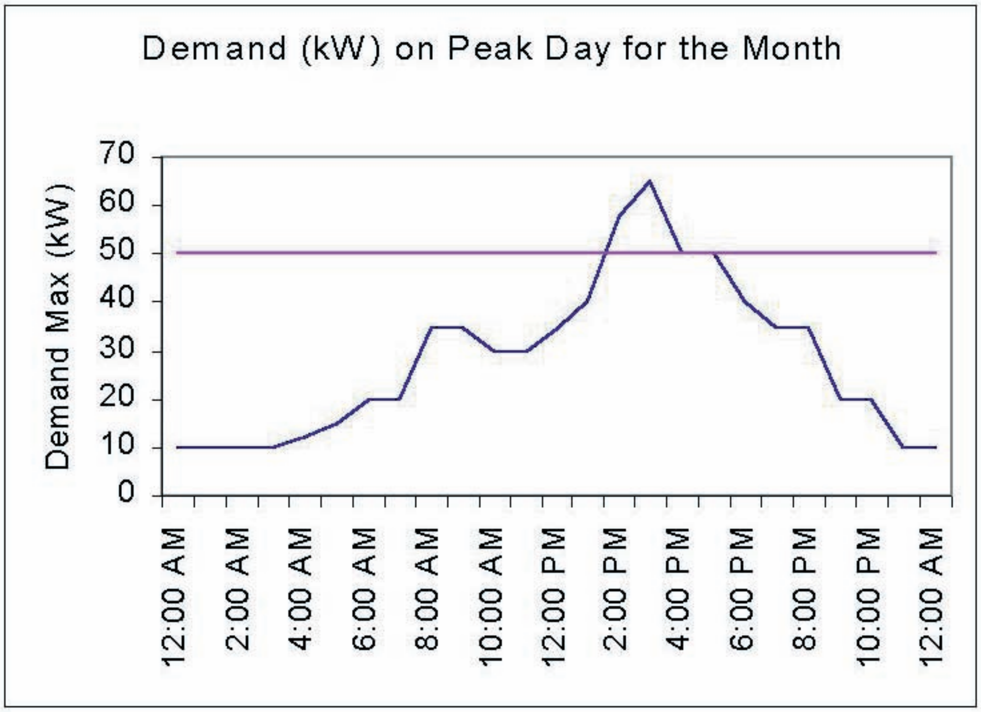
Reflectivity, or albedo, is a measure of the amount of solar energy reflected away from a surface. Typically, reflectivity has a major impact on solar energy in the visible range and has a less significant impact on energy in the UV or near infrared range.

Reflectivity is usually presented as a ratio or percentage. For example, a highly reflective roof product might have an initial albedo of 0.85, which means 85 percent of the solar energy is reflected.

A reflective roof surface can help reduce the amount of building heat gain in two ways. First, by reducing the temperature of the roof surface, the amount of heat that passes through the roof assembly into the air-conditioned interior is reduced. Reducing the amount of heat that enters via the roof reduces the amount of energy required to cool the interior.

Second, by reducing the temperature above the roof surface, the HVAC units can draw cooler intake air (also known as "make-up air"). Since many air intakes are positioned near the roof surface, reducing the make-up air temperature can improve system efficiency significantly, particularly in light of ASHRAE increasing the standard for the amount of fresh air intake per minute per person (ASHRAE Standard 62-1999). It is worth noting that HVAC make-up air circumvents the roof system's insulation, regardless of how well the roof is insulated. Warmer make-up air impacts the efficiency of the HVAC system, which adds to the amount of energy required to maintain interior comfort. Reducing the temperature above the roof surface can lower the temperature of the HVAC make-up air, improve the cooling efficiency of the units, and lead to downsizing the HVAC equipment for optimum efficiency and performance.

Figure 2



The pink line is the "on-peak" kW level set at 50 kW.

Image provided by Elastomeric Roofing Systems (ER Systems)

Understanding the influence of reflective roofs on the cost of energy requires a look at how a typical commercial energy bill is determined. Although utilities may vary the factors used to calculate commercial energy costs, there are three basic components that are important to understand. The three components of direct energy costs include the monthly fee, energy charges, and demand charges (or ratchets). The monthly fee is usually a fixed dollar amount that is charged to the customer. Energy charges refer to the amount of energy used as expressed in kilowatt-hours (kWh). Energy charges are determined by multiplying the amount of energy used (kWh) by the rate, or the price per kWh. Rates vary among utilities and some utilities use a multi-tiered rate schedule. For example, the Texas Utilities Electric Company charges $0.0621 for the first 2,500 kWh and $0.0320 for all additional kWh used.

Demand charges (or ratchets) are not based on the amount of energy used, but are based on "peak" and "non-peak" demand expressed in terms of kilowatts (kW). (See *Figure* 2). Demand charges are determined using the on-peak demand and the current month's peak demand. Typically, on-peak demand is determined by a facility's peak demand during the months of June through September. What is equally important to understand is that when the peak demand at any given time exceeds the on-peak demand level, the utility will re-set the on-peak level for the next year based on the highest peak demand recorded. For example, a facility might have a current "on-peak" demand level set at 50 kW. However, if during the months of June through September, the facility's peak demand achieves a high of 65 kW, then the new on-peak demand level for the next year will be set at 65 kW. As this example illustrates, reducing peak demand (or not exceeding the on-peak demand level) can have a significant impact on the end user's energy costs.

Minimizing peak loads can have an impact on annual utility costs in northern parts of the country as well. Cities such as Chicago and Minneapolis experience heat events that frequently result in buildings establishing new on-peak demand levels. While the number of cooling degree days in the northern parts of the U.S. are fewer than in the southern regions, avoiding peak loading can prevent higher utility costs, brown outs, and loss in productivity in many parts of the country. In addition, facilities typically cool with electricity and heat with an alternative fuel. The price for electricity can significantly exceed the price for the heating fuel. Considering these basic concepts is important when trying to understand how a reflective roof system can provide additional performance—such as lowering a client's energy bills —beyond the traditional roof performance criteria.

Isolating the benefits of a reflective roof surface can be fairly complicated and challenging —though not impossible. Reference 4 discusses the factors affecting the energy savings available from changing roof reflectivity. In fact, a number of manufacturers and researchers either currently have or are developing software that can isolate and estimate the impact of a reflective roof

THE ENERGY STAR® ROOF PRODUCTS PROGRAM

The United States Environmental Protection Agency (US EPA) and the Department of Energy (US DoE) are drawing attention to the benefits of reflective roofing products through the Energy Star® Roof Products Program. The Energy Star Roof Products Program has been in existence since February of 1999 and works to educate roofing professionals and the general public about the benefits of reflective roofing. Manufacturers of roofing products voluntarily join the Program by signing a Memorandum of Understanding (MOU). Manufacturers that join the Program either have or will have products that qualify according to the criteria listed below. Joining the Program does not mean that all of a manufacturer's product line qualifies as Energy Star®. After signing the MOU, manufacturers can use the Energy Star® Logo to identify qualifying products only. Manufacturers self certify their qualifying roof surfacing products based on minimum values for initial solar reflectance and reflectance after three years of in-field weathering. The solar reflectance qualifications are as follows:

CHARACTERISTICS	**LOW-SLOPE ROOFS*** (Surfaces with a slope of 2:12 inches or less.)	**STEEP-SLOPE ROOFS*** (Surfaces with a slope greater than 2:12 inches.)
Energy efficiency		
Initial solar reflectance.	Greater than or equal to 0.65.	Greater than or equal to 0.25.
Maintenance of solar reflectance.	Greater than or equal to 0.50 three years after installation under normal conditions	Greater than or equal to 0.15 three years after installation under normal conditions
Reliability		
Manufacturer's warranty for defects in materials and manufacturing.	Each company's warranty for reflective roof products or roof coatings must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof products and coatings. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.	Each company's roof membrane product warranty for reflective roof membrane products must be equal in all material respects to the product warranty offered by the same company for comparable non-reflective roof membrane products. A company that sells only reflective roof products must offer a warranty that is equal in all material respects to the standard industry warranty for comparable non-reflective roof products.

*For roof products that can be applied to either low-slope to steep-slope roofs, manufacturers should qualify their products based on the low-slope values.

To date, Program Partners have self-certified and submitted over 50 qualifying roofing products meeting these qualifications. These products include single-ply membranes, roof coatings, and metal roofing products. A number of case histories demonstrating the benefits of reflective roof products are available while others are in development. In addition to staffing booths at a number of roofing trade events (including RCI in 1999 and 2000), the Energy Star® Program has communicated its message at an RCI Region 1 event (Dec. 3, 1999) and at RCI's Reno, NV, convention in March 2000. For more information about the Energy Star® Roof Products Program, visit the program's web site at http://www.epa.gov/appdstar/roofing. A paper on the Energy Star® program occurs in the *Proceedings of the North American Conference on Roofing Technology* (1999).

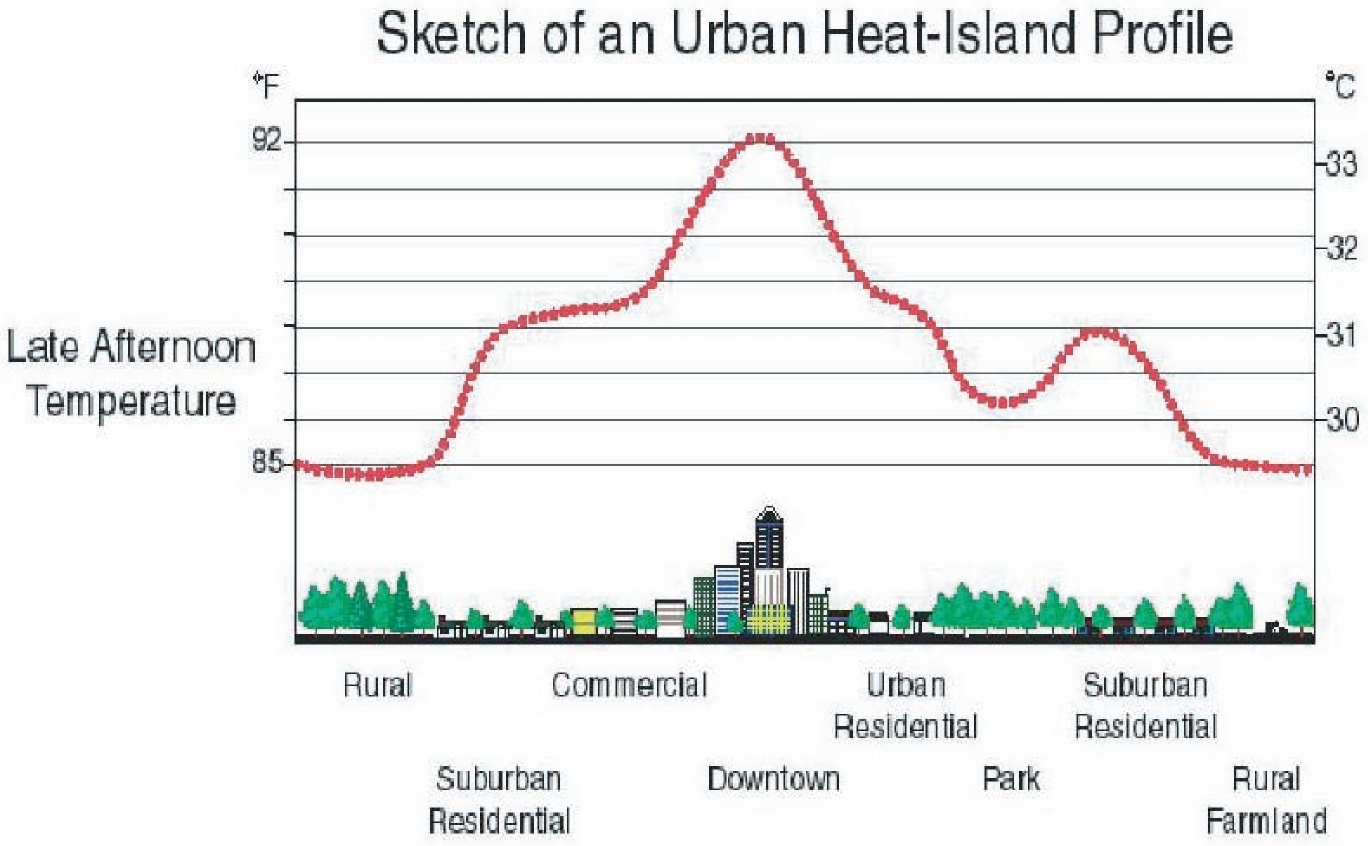
on the energy consumption of a building. A number of these models rely on DOE2 as the basis for analysis, while others incorporate ASHRAE research, such as the ASHRAE "clear day method" and its subsequent modifications, which account for elevation and the differences in the incident angle of light during the summer and winter months. Later this year, the ORNL web site previously mentioned will have a new calculator for determining the economic benefit of reflective roof surfaces.

Reference 5 provides an interesting comparison of a house sited in Alabama, Arizona, Florida, North Dakota, and Maine. Estimated annual energy costs were calculated using reflectance values ranging from 0.1 to 0.8, and roof insulation values ranging from uninsulated to R-38. Even in the northern states, increased roof reflectivity resulted in reduced annual and peak cooling loads.

Reflective roofs provide other benefits in addition to energy conservation. They minimize membrane heat aging and thermal shock. Some reflective surfacings also reduce UV degradation. Minimizing these destructive factors can extend the service life of the roof.

Heat islands: Increased roof reflectivity is one of a number of strategies that help mitigate the urban heat island effect, which has a community-wide impact on overall energy use, air quality, and human health. Urban heat islands occur in areas characterized by non-reflective roof and ground surfacing materials and a lack of shade trees. Urban heat islands can be up to ten degrees F. warmer than the surrounding areas (*Figures 3* and *4*). Urban heat islands contribute to increased levels of air pollution (e.g., NOx, SOx, and ground level ozone) and increased cooling demand. While extrapolating the benefits of reflective roofing to the community level is beyond the scope of this article, stakeholders at the national, state, and local levels are continuing to research and model urban heat islands and various mitigation strategies. For utilities, reducing the overall solar load at the community level could have a positive impact on the entire electrical distribution system. Consultants and contractors can enhance their services by understanding the issues pertaining to

Figure 3



Source: Lawrence Berkley National Laboratory (LBNL)

urban heat islands and learning more about the Energy Star® Roof Products Program (see sidebar, page 22). For further information about heat islands, visit the Lawrence Berkeley National Laboratory web site at http://eetd.lbl.gov/heatisland, or refer to Reference 6.

Other factors affecting the solar reflectance of roof surfacing materials include environmental considerations such as industrial pollutants, dirt, and biological growths such as algae. Typically, the initial solar reflectance will decrease the most during the first year, but after three years the reflectance value remains relatively constant. Therefore, while initial solar reflectance is important, maintaining solar reflectance in order to optimize energy savings can be both a challenge and an opportunity. As a challenge, many building owners still approach the roof from the perspective of "out of sight, out of mind." As an opportunity, promoting best maintenance practices and implementing a periodic cleaning schedule create a proactive strategy to inspect the roof and identify problems in advance of an emergency situation. Depending on the roofing product installed, slope, and other factors, some reflective products outperform others with respect to dirt adhesion on the surface.

Reroofing

Reroofing often provides an opportunity to substantially decrease the building owner's expenditures on energy costs. In addition to increasing the amount of thermal insulation and specifying a reflective surface (where appropriate), consideration should be given to HVAC equipment upgrades. For those buildings with inefficient roof systems, upgrading to a highly efficient system will create less demand on the HVAC equipment. By replacing the equipment with units that are sized to suit the new demand, significant operational cost savings can be achieved. Replacing HVAC equipment is particularly attractive when the equipment is nearing the end of its useful life. By replacing the equipment at the time the building is reroofed, not only does the owner receive reduced operational costs, but the roof is not vulnerable to damage a few years later when the old equipment would have otherwise been replaced.

A reroofing project that enhances both the efficiency of the roof system and the HVAC equipment can result in substantial cost savings to the owner.

Maintenance

Significant energy savings can be achieved on many poorly insulated buildings by the addition of a highly reflective roof coating. Also, those buildings that are not air-conditioned can be made more comfortable with a coating. Case studies have documented that energy savings have greatly exceeded the cost of coating a lightly insulated roof.

For roofs that have reflective roof surfaces, periodic cleaning of the roof surface may or may not be cost effective. Because the roofing industry has limited experience with roof cleaning, a careful evaluation should be performed to determine if cleaning is cost effective. Also, the cleaning method should be evaluated to ensure that the cleaning is not detrimental to the roof.

Code

When designing new or reroofing projects, it is important to determine if there are energy efficiency requirements in the local building code or other regulations. For example, Chapter 13 of the new International Building Code requires buildings to be designed in accordance with the International Energy Conservation Code, and the Georgia State Energy Code includes reflectivity requirements.

Summary

Designers who consider and advocate energy efficient design provide value-added service to their clients. Building owners who are willing to pay for enhanced energy efficiency will undoubtedly experience a good return on their investment via decreased expenditures for energy consumption and greater occupant comfort. Although the high energy prices of this year are expected to decline, there is nothing to suggest that inexpensive energy is in our future. Designers can also have an impact on the environmental quality of urban areas. Although specifying a highly reflective roof on a single building has negligible environmental influence, with concerted effort, within a few years most urban roofs can be transformed from heat absorbers to heat reflectors. This transformation will have a significant positive influence on our urban environments.

Anthropologist Margaret Mead said, "Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has." Energy efficient design moved forward after the 1973 Energy Crisis. It is time to move it further, particularly with the increased availability of highly reflective roofing products and the new findings pertaining to heat islands. ■

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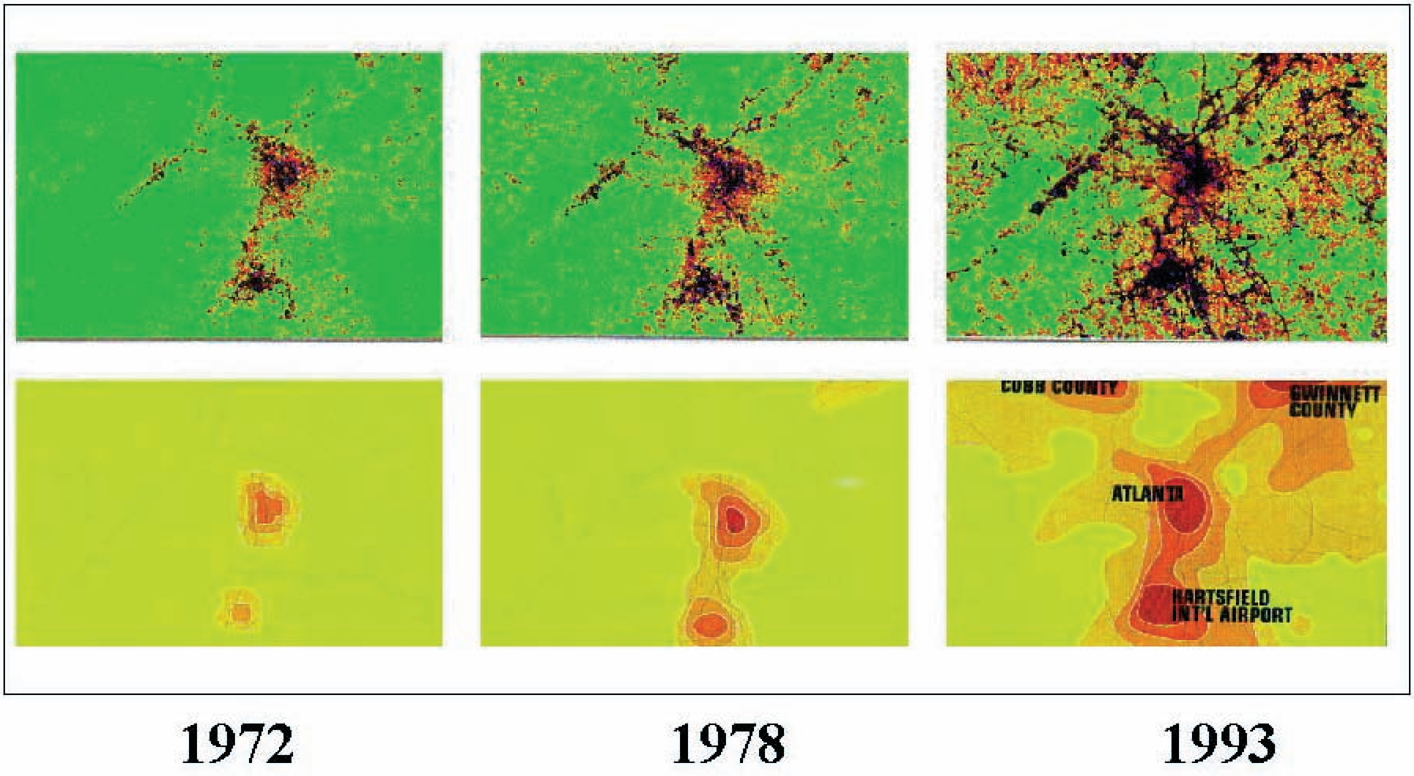
Figure 4

Atlanta's Changing Environment



Source: Oakridge National Laboratory (ORNL)

SAMPLE ENERGY BILL CALCULATION

Commercial energy bills are typically comprised of three components: a customer fee, energy used, and demand charge. Following is an illustration of how an energy bill is calculated for a facility that consumes 14,000 kWh in a given month.[1] This example assumes that the basic customer fee is $15.00, the price for energy up to 2,500 kWh is $0.0621 per kWh, and the price for energy over 2,500 kWh is $0.0320 per kWh. The other assumptions are that the current on-peak demand level is set at 50 kW and that during the month the facility reaches a new peak of 65 kW. (See *Figure* 2).

COMPONENT OF BILL	**COST**	**% OF TOTAL BILL**
Customer Fee	$15.00	2 %
Energy Used		
2,500 kWh x $0.0621	$155.25	18 %
11,500 kWh x $0.0320	$368.00	42 %
Demand Charge[2]		
Demand in excess of 10 kW		
(53.75 kW - 10 kW) x $7.63	$338.81	38 %
TOTAL	$872.06	100%

In this example, the demand charge accounts for 38 percent of the total energy bill. Even more important, the new on-peak demand is raised from 50 kW to 65 kW, a difference of 15 kW. At $7.63 per kW (and assuming that for the next 12 months the facility does not achieve a new peak load in excess of the newly-set, on-peak level of 65 kW), the additional 15 kW of on-peak demand can increase the end user's bill by $114.45 per month (15 kW x $7.63 = $114.45). Interestingly, it is not uncommon for demand charges to account for up to 50 percent of the total energy bill. Reducing the amount of energy used as well as lowering the peak load are two important factors when considering the energy impacts associated with specifying a reflective roof product.

[1] This example is based on the Texas Utilities Electric Company fee schedule and was provided courtesy of Elastomeric Roofing Systems Incorporated (ER Systems, Inc.). Please note that rates may change or vary depending on usage. Example is for illustrative purposes only.

[2] In this example the demand charge of 53.75 kW is calculated by adding to the current on-peak level 25 percent of the difference between the current on-peak level and the new peak achieved during the month. Specifically, this example assumes a current on-peak level of 50 kW and a new peak event at 65 kW. Thus, 53.75 kW = 0.25 x (65 kW - 50 kW) + 50 kW.

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Thomas L. Smith is a licensed architect and a registered roof consultant. His interest in roofing began in 1974, two years after receiving his Bachelor of Architecture degree from the University of Arkansas. Prior to establishing TLSmith Consulting Inc. in 1998, Mr. Smith was the Research Director for NRCA. Prior to his position with NRCA in 1988, he was in private practice in California and Alaska. TLSmith Consulting Inc. specializes in architectural technology and research, with an emphasis on roof systems. Smith serves on the American Society of Civil Engineers (ASCE) committee that is responsible for ASCE 7, Minimum Design Loads for Buildings and Other Structures, and he is a member of the subcommittee on Wind Loads (since 1990). He was elected to the Board of Directors for the American Association for Wind Engineering in 1998. He is also on the international CIB/RILEM Joint Committee on Roofing Materials and Systems (since 1989), the review committee for the update of the Federal Emergency Management Agency's Coastal Construction Manual (since 1997), and the Technology Assessment and Advisory Council for the Colorado State University/Texas Tech University Cooperative Program in Wind Engineering (since 1989). Mr. Smith is also on the faculty of RIEI.

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Drew Gagliano is a senior associate at ICF Consulting in Washington, DC. For the past three years, Mr. Gagliano has provided program support to the U.S. Environmental Protection Agency's (EPA) Energy Star® Programs. Specifically, Mr. Gagliano has helped EPA develop and implement the Energy Star® Roof Program a global market transformation program that promotes the environmental and energy saving benefits of reflective roof products. Prior to joining ICF Consulting, Gagliano worked for six years in the Facilities and Operations Management division of the Hertz Corporation. He has Masters degrees in Environmental Science and Public Policy from Indiana University.