The Energy Management Benefits of Reflective Roofing

By David R. Hawn, RRC, CEM and Ron Abremski

Abstract

Energy Star™-labeled reflective roof materials and coatings were introduced to the industry in 1999. Energy Star™ partners, qualified products, and curiosities concerning benefits have substantially increased since that time. Reflective roof surfaces can, from an energy management perspective, have a positive impact on reduced electric utility costs. In many case,s the payback period for an Energy Star™-labeled roof surface is immediate. At the same time, the environmental benefits from reduced consumption of electric utilities are of great value. Some of the methods one can use to consider the savings are presented and the understanding of commercial utility rates are explored. This information, coupled with a keen eye for additional energy and other related benefits, can provide substantial cost savings and advantages.

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THE ENERGY MANAGEMENT BENEFITS OF REFLECTIVE ROOFING

INTRODUCTION

Roofing, and particularly roof surfacing, can have an impact on energy consumption at commercial facilities. Peak loads and electrical energy consumption are especially affected. The Energy Star™ labeling program developed by the Environmental Protection Agency (EPA) is a tool that can help reduce peak loads, energy costs, and consumption.

Energy Star™-labeled roof products provide a number of benefits roof consultants should consider. Those benefits include: direct and indirect energy savings, environmental benefits, and roof performance benefits. The energy savings aspect as it would relate to facility energy management is the focus here but other benefits may also be of interest.

The Energy Star™ program first became a known entity when it was presented at a Federal Roof Committee Meeting. Shortly thereafter was the first annual meeting of Energy Star Partners in Atlanta, Georgia, in conjunction with the National Roof Contractors Association (NRCA) Convention. Obviously, the advertising of Energy Star™ and the gathering of partners to the program began before these events.

Energy Star Labeled Roof Products

The United States Environmental Agency (US EPA) and the Department of Energy (US DoE) have been attracting attention to the benefits of reflective roofing products through Energy Star™ Labeled Roof Products. Since its launch in February of 1999, Energy Star™ has worked to educate roofing professionals and the general public about the benefits of reflective roofing. Manufacturers of roofing products voluntarily participate by signing Partnership Agreements. Participating manufacturers have products that qualify according to the Energy Star™-Labeled Roof Product specifications.

Manufacturers self certify their qualifying roof surface products through specific ASTM testing procedures that include minimum values for solar reflectance and reflectance after three years of in-field weathering. Manufacturers that qualify reflective roof products for Energy Star™ can then use the Energy Star™ logo to identify qualifying products only.

Currently, participating manufacturers have qualified over 100 reflective roofing products that have met these standards. These products include single ply membranes, metal roofing products, coatings, and tile products. A number of case histories demonstrating the benefits of reflective roofing products are available while others are in development. For more information about Energy Star Labeled Roof Products, visit the Energy Star Web site at http://www.energystar.gov/products

The 2000 convention in Reno was the first introduction of Energy Star™ to the Roof Consultants Institute (RCI). The presentation made, at that time, included a roof consultant's perspective. The September issue of RCI's *Interface* featured an article authored by Thomas Smith, AIA, RRC, and Drew Gagliano. It included many of the points presented at the 2000 Convention and additional information focused on energy and environmental conservation. Those presentations allowed a better insight into the Energy Star™ program developed by the EPA for positive environmental impact. There are a number of related associations and areas of research, including the Cool Roofs Rating Council and studies concerning urban heat islands that include roof reflectance.

Energy Management

The Association of Energy Engineers provides an educational program in energy management and continuing education on energy-related issues. It is an excellent resource of educational programs to allow one to learn more about energy management and, if desired, to write an examination to become a Certified Energy Manager.

Energy management is a function of both energy consumption and cost reduction. All aspects of energy are considered during an energy management audit, including fuel procurement (i.e. electricity, gas, oil, diesel, and others). With deregulation, this area may be of even greater importance. The building envelope is an important aspect of the audit, but generally the largest cost savings typically are found with motor efficiency, fuel use, recovery methods, and HVAC plant components. Many things are included in an energy audit such as those shown in the table below.

Instrumentation	HVAC and Thermal Energy Storage	Energy Accounting
Utility rate structures	Economic analysis and life cycle costing	Lighting
Motors and applications	Electrical system utilization peak load control power factor correction	Insulation
Fuels used	Waste heat recovery Cogeneration	Controls
Alternative financing	Boilers and thermal systems	Maintenance

The building envelope and reflective roof surfaces at some facilities have a small overall impact in the scope of a total energy management audit. However, the cost-to-savings benefit ratio analysis is likely to prove Energy™-labeled roof products and coatings to be a wise decision.

The Energy Management Benefits of Reflective Roofing

Direct energy savings result from Energy Star™-labeled roof products during the cooling season. When air conditioning and heavy use of electricity are dependent upon that function, peak demand loads are set through higher rates of consumption during utility service peak periods. These increases in peak demand loads impact electric utility use charges, demand charges, and the environment. Managing and reducing peak demands allow generation plants (utilities) to control their production for optimum performance and efficiency that, in turn, affect pollution and consumer cost.

Direct energy savings come to building owners in two ways: through reduced use and reduced peak demand. From an energy management perspective, we will focus on the direct energy savings, although indirect benefits can also be added to these savings. For some environmentally-minded building owners, the indirect benefits—primarily environmental impact and urban heat island reduction—may even outweigh the justification provided by direct energy savings.

We will first turn to the cost-benefit ratio. In many cases there is no additional cost of using an Energy Star™-labeled roof product or coating when compared to a non-labeled product that would be used anyway. In these cases, the calculation of savings is easy. Since there is no additional cost, the issues of savings calculation and payback periods are not needed. Energy Star™ has included, as a part of its labeled roof product program, the qualification that performance warranties of the labeled roof product must be equal to or better than those of non-labeled products. In cases where the cost of utilizing an Energy Star™-labeled roof product represents an increase in the project cost, two things, in addition to the additional cost, are needed to evaluate the benefit. First, the direct energy savings needs to be calculated. Second, the payback period must be evaluated. Oak Ridge National Laboratories (ORNL) and Lawrence Berkley Laboratories (LBL) have developed some useful aids to demonstrate the savings. These can be found at their respective websites. The calculator being developed by ORNL is the model used here for the calculation of savings. Energy Star™ also has a roof savings calculator under development but it is not yet ready for use. Along with any calculation method used, an understanding of a commercial electric utility billing and rate structure is needed. Once the cost savings information is known and effects of the applicable electric utility costs are understood, the life of the product or coating and desired payback period must be considered.

When the payback period cannot be met or the life of the product is exceeded before payback or break-even occurs, the added cost cannot be justified. Some clients will already have a payback period established for their operations, ranging from one to ten years. If they do not, the consultant must make a judgment of a reasonable pay-back period. Clearly, if the cost can be recovered long before the component reaches the end of its useful life, the economics justify the expense and can be shown to the client as a positive added initial cost. Other factors such as the anticipated cost increase in utilities, the cost of financing additional initial project costs, and maintenance costs may need to be factored into the equation for a complete economic analysis.

There are many variables to factor out of the complicated longhand equations to calculate savings. Those variables make the results less dependable and, if included, the time to calculate the potential savings is significant. The longhand results only represent selected conditions. Without computer modeling, calculations at each angle of incidence, temperature, other climatic and physical site conditions that change monthly, daily, and hourly, represent multiple calculations that would need to be performed. Due to this fact, there are several demonstrations of savings resultant from reflective roof surfacing. Some resources that allow viewing of these demonstration results include web sites for ORNL, LBL, or the Florida Solar Energy Center (FSEC). These sites represent only a few of the sites with this type of information. The demonstrated savings vary greatly, even for similar roofs in similar locations. This is due to the variables that apply. Data has been gathered for about ten years through research projects and the information has been annualized. This process has allowed for some calculators to be developed. The FSEC site has a calculator available at its website based upon Department of Energy-2.1e (DOE2.1e). This is a commercial building energy simulation software fully capable of simulating the impact of roof reflectance but not as a variable parameter.

Numerous calculation tools are in development and several are available for use now. The extent of data used in model development should be reviewed to understand the averaging of data. Most provide annualized savings that account for at least one year including winter and summer cycles. Some may include more than one year of data in the modeling that allows for some confidence concerning the roof surfaces becoming less reflective over time. With additional time and study, it is likely that the calculator will even better factor in the fact that the roof surface will become dirty and less reflective. All calculator models must include some assumptions but model results compared to field measurements tend to be underestimated. In discussion with representatives from FSEC concerning the DOE-2 based calculator, it was presented that the underestimation averages about 5%, with the greatest underestimation occurring at facilities with ducted air conditioning directly beneath the roof deck. At these locations, the coolest air is being ducted through the hottest space, typically with poorly insulated ductwork.

The calculators available, and especially the one to be introduced at the ORNL web site, are generally based upon demonstrated savings and data gathered from instrumentation in the field. One item these calculators do not generally include is the impact on demand cost charged by electric utilities. This cost varies among utility companies but can be a major part of a commercial electric service utility bill. It has been shown that demand charges alone can account for between 38% and 50% of a total commercial electric bill. We will review a commercial utility rate structure for a better understanding of demand charges.

With the assistance of ORNL, we have been allowed access to the calculator that will be demonstrated at RCI's 16th International Convention in Baltimore, MD. This calculator will be available at the ORNL web site soon thereafter. The utility rates used in the example below were gathered from Potomac Electric Power Company (PEPCO). The underlined components were entered into the calculator:

30,000 square foot commercial building

State of <u>Maryland</u> and City of <u>Baltimore</u>

R-value of <u>10</u> – arbitrary selection

<u>0.65</u> solar reflectance –minimum allowed by Energy Star™ for initial conditions

Infrared emittance of <u>0.65</u> – selected from a list of manufacturer data

Average summer cost of electricity <u>$.0042</u>/KWh – derived from PEPCO rate schedule

Air conditioner COP* <u>3.0</u> – a value for typical small chiller (typical range from 2.5 to 7.0)

Energy source for heating using gas at <u>$0.70</u> per therm – derived from PEPCO

Heating system efficiency <u>.70</u> – a value for a moderately-aged gas fired boiler

* COP is Coefficient Of Performance

The resultant overall savings for this example would be $0.0071 per square foot per year. For the 30,000 square foot facility, the overall savings based upon KWh use is $213 annually. The cooling savings calculated was $0.0157 per square foot per year relating to $471 annually. Cooling savings is important because it allows for a better correlation with demand charges. Because the ORNL calculator is based upon demonstrated or measured data, savings and losses as well as several other variables are factored into the results it provides. The program will allow you to make your own assumptions concerning the entered data. Because the only utility cost entered is electricity on a KWh basis, one factor that is not included is the peak demand charge. To understand this, we need to look at a commercial electric rate structure.

The PEPCO website offered an easy view of the commercial rate structures for commercial buildings in Maryland. Several rate structures are available, but most commercial facilities are on a time-metered schedule, meaning the cost of electricity varies with the time of day use. Schedules are set for facilities based upon demand. Another way to reduce electric energy cost is to reduce consumption and peaks to allow for a change in the schedule used.

Distribution charges		
Customer charge	$275.67 per month summer and winter	
Kilowatt-Hour (KWh) charge	$0.00590/KWh summer and winter	
Kilowatt (KW) charge	$1.7738/KW on peak summer	
	$0.7350/KW maximum other times.	
Transmission Charges		
Kilowatt-Hour (KWh) charge	$0.00265/KWh summer and winter	
Kilowatt (KW) charge	$0.7154/KW on peak summer	
	$0.2940/KW maximum other times.	
Generation Charges		
Kilowatt-Hour (KWh) charge	Summer	Winter
On Peak	$0.03994/KWh	$0.03265/KWh
Intermediate	$0.03323/KWh	$0.02708/KWh
Off Peak	$0.01745/KWh	$0.01438/KWh
Kilowatt (KW) charge		
On-peak	$7.39/KW	
Maximum	$3.04/KW	$3.04/KW

Rating periods were defined as follows:

Summer—June to October   Winter—November to May

On Peak—12 noon to 8 PM   Off Peak—12 midnight to 8 AM

Intermediate—8 AM to 12 noon and 8 PM to 12 midnight

Billing demand for monthly on-peak summer is defined as the maximum thirty-minute demand for the billing month.

Billing demand for all months is defined as the maximum thirty-minute demand for the billing month.

The schedule information presented below, in short form, is the current Maryland (MD) – GT 3A (General Service – Primary Service). Rates charged include:

One can see from this description of the rate structure that the demand charge is not only a substantial part of the overall bill but varies with consumption of electricity. In the summer months, not only is the billing demand charge impacted but also the on-peak demand charge. Even though one saves on the amount used, they also save when demands are set at lower levels. The demand charge applies for all months and is set on a monthly basis. In the summer months, the peak is set during the peak demand period and is charged, in addition to the demand charge, for the summer period and calculated similarly. This makes for high summer period electric utility bills.

Some electric utilities set demand ratchets that take the highest demand set for the peak period and then apply a generation charge at a percentage of 60% to 100% that continues for the next 12 months or until a new peak is set, in which case, the new higher charge applies until it is either exceeded or 12 months pass. Demand charges are the way capacity costs are assessed to the customer. In essence this is the way new electric generation facilities are funded, at least in part. Reducing demand is a very effective way to reduce the electric utility costs overall. It is the high peak demand cost that provides incentive for energy saving ideas like thermal energy storage, allowing cooling in the summer season to be done off-peak, when rates and demand charges are lower. The stored cooling energy is then used during the peak cooling period to reduce the electric demand load.

If the electrical use during the cooling season exhibits a ten-percent reduction, it would be a very conservative estimate that the summertime peaks would be affected by at least that amount, or a 10% reduction. Field studies by LBL and the Florida Electric Power Coordinating Group have reported a 10% reduction in annual energy savings and a 30% reduction of peak load. In another study by the FSEC, an average consumption was reduced by 25.3% with an average peak demand reduction of 40% of that amount. This peak demand charge savings for the summer months should be added to the savings calculated above. In the process of research, the electrical utilities were very helpful in presenting their rate structures and are typically eager to help clients reduce their common peak demand loads.

A conservative estimate of demand charge savings is calculated here from the cooling load savings calculated and noted above at $471. This example is provided to avoid the publication of an actual customer bill. With the following assumption,s a conservative savings of $164.50 is realized. The value obtained is presented for example purposes by considering the typical percentage of utility bill accounted for by demand charges at a conservative 35% (noted above to be 38% to 50%). With summer season savings at $471, we will assume this represents a 10% savings consistent with the results of several demonstrations published. Therefore, the total bill (cooling season) would be estimated at $4,710. The 35% estimate (conservative) of demand costs associated with a $4,710 bill would represent a demand cost of $1,648.50 during the cooling period. If ten percent were saved on the demand costs as well, $164.8, in additional saving should also be accounted.

For actual demand savings analysis, obtain the actual electric utility invoices, or summary of use and demand charges, from the building owner. From the savings calculated, obtain the percent of use (KWh) savings by dividing the calculated annual savings by the annual use charges. The percent of demand charge (KW) savings to apply as related to reduction of the use charges can be calculated by multiplying the summer month peak and maximum demand charges by the percentage of use savings. The demand charge savings actually have been demonstrated by field study, as noted above, to be greater than the percentage of use savings. Research information may eventually allow us to identify specific percentages of demand savings. Until then, it is probably best to error on the conservative side. Remember, we are considering the cooling savings exclusively, so they apply only during the summer rate period defined by the electric utility.

If the calculated savings based upon KWh rate are applied and a conservative demand charge savings is added, for this example, we obtain a total savings of $377.50 on an annual basis. The Energy Star™-labeled roof product chosen may add no additional cost. In that case, the savings is apparent. However, if a product that increases the cost of the project by $0.10 per square foot or $3,000 in additional initial investment is chose, be sure to deduct any components not used from the cost of the product being added to the project to arrive at the square foot added cost. For simplicity, first divide the initial additional cost of $3,000 by the savings per year of $377.50. On a cost-to-benefit basis, it would take 7.9 years to pay back the original investment for the Baltimore, MD roof. The calculations were run with the same parameters (except the building location) for Tampa, Florida. For Tampa, the payback period was 2.5 years, using the same criteria and assumptions.

Clearly, if the payback occurs in the first year or less, the issues of cleaning and maintenance, expected life of the product used, and other similar factors are of less importance. If it is likely the product may need to be refreshed or reapplied before the end of the life of the roof, the consultant may want to check the payback of the product chosen on the cost basis in current-day dollars. Of course, both the cost of reapplication and the cost of the electric service are likely to rise with time and should be considered.

If the payback occurs after more than one year, an economic analysis may be called for. If satisfied with the results from the cost-to-benefit analysis, calculations may stop at this point. If not, check the calculator model being used to be certain it does not already include real world reduction in reflectivity over a reasonable time period. If it does not, it may be desirable to include adjustments for service and performance of the reflective surface beyond the one-year period. If the model being used only uses a one-year period starting with a clean roof, the maintenance cost of cleaning the roof surface and frequency of cleaning should be considered. This adds to the cost side of the equation. If premium performance of the reflective coating is desired, it may be wise to clean the roof at least once each year at the beginning of summer (also a good time to check for roof maintenance and repair items).

Once the costs associated with maintaining the reflectivity level desired are known, the economic analysis may begin. The savings for the first year will stay the same as calculated above. If the solar reflectance factor is modified, the savings will change for subsequent years and should be added accordingly to the first year savings for the number of years used for the analysis. If there is not an established pay-back period (defined by the building owner,) the life of the product must be determined. Of course, this will vary based upon the product being used. It may be desirable to use the warranty period offered by the Energy Star™-qualifying roof material being used. With the savings, costs, and period of service or payback desired, then perform a thorough economic analysis and include other factors important to the client, possibly including anticipated energy cost increases, longevity of the roof, and the cost of financing the initial investment over the payback period.

Some other areas of energy management related to roofing include keeping an eye out for "energy gobblers." Many roofs have penetrations and conditions that result in wasted energy and increased energy cost. They can be treated to avoid that loss when identified. Obviously, the thermal insulation system at the roof is important. The NRCA has a publication, The *NRCA Energy Manual*, which is helpful with the consideration of energy loss and the value of adequate insulation. Some of the calculators noted above also assist with this function. Also, look for breaks and breeches in the thermal envelope. They can typically be found at the roof area perimeters and penetrations. These thermal breaks not only result in energy loss but also occasionally generate leak symptoms due to condensation.

Some expansion joint details only allow for a fraction of the R-value prescribed for the remainder of the roof. Ventilation can also be a factor that either enhances or reduces thermal transfer resistance. As an example, the use of an inverted roof system with drainage channels that are vented to the outside air dramatically reduces the value of the insulation, allowing the outside air to flow across and in direct contact with the structure beneath the insulation similar to venting an attic space. Assure there are thermal stops that do not allow the channel areas to become vented air spaces. Skylights, gravity vents, and other open chases from the inside to the outside with little or no resistance to heat flow may exist and should be treated. In the case of skylights, also consider the solar gain directly into the space, thereby dramatically increasing the heat load. Some shading or tinting may provide substantial benefit.

Other benefits of Energy Star™ roof products to the roof may also be of consideration. A reflective roof surface will reduce surface temperatures. Reduced roof surface temperatures can provide improved resistance to thermal shock caused by rapid cooling. Reduced ultraviolet aging of products that otherwise do not perform as well when exposed to the sun also provides a benefit. It is clear from many roof surveys that roof flashings perform better when a reflective surface is used. This is also indicated at the surface of south-facing flashings that deteriorate more quickly due to solar exposure. These indicators are telling us something and it applies to the entire roof surface. To maintain reflectivity at its optimum level, it may be wise to consider periodic cleaning that could be coupled with preventive maintenance rooftop checkups. This would pay serious dividends to the roof performance while maintaining the reflectivity.

The environmental benefits are something in which we should all have an interest. Thirty years ago, air quality indices and ozone levels were not part of our local weather forecasts. They are today. What will we hear thirty years from now? Will the local weather report include the level of filter we need to use in our respirators? If the trend continues, the future may be clouded with smog. The prospect sounds grim, but could become a reality.

Conclusion

Electric energy consumption is reduced by the use of Energy Star™-labeled roof products. This affects both the charge based upon rate of use and demand for commercial facilities. There are calculators available to evaluate the savings and more are being developed. The demand charge savings should be included in the evaluation of total savings. The use of Energy Star™-labeled roof products provides cost savings and environmental benefits. As energy costs and demand continue to rise, the resultant savings and environmental benefits will become even more important.

At some facilities, the energy management impact or savings from Energy Star™ roof product use may be small, but every little bit helps. Everyone and every company make economic choices every day. We now have even more tools to understand the impact of technology. It is rare when we can choose to save money, improve roof performance, and benefit the environment at the same time. The additive benefit to society through environmental impact can be substantial, even on a small, incremental basis. One person clapping does not make much noise, but 50,000 people clapping can be quite a force. The same is true with the savings resultant from Energy Star™-labeled roof products. One 30,000 SF facility saving $377.50 annually may be considered a small savings, but if all the 30,000 SF facilities in just one major city were to do the same, the impact on the electric utility demand would be tremendous. So, start clapping—we all win.

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