Economic Feasibility of Cleaning Roofs to Maintain their "Solar Reflectance" Ratings

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Traditionally, very few roofs are cleaned during their lifetime. The roofs that do get cleaned are usually on food processing facilities or other buildings where the accumulation of biomass or other process debris deposited on the surface could be detrimental to the roof or to the products being manufactured inside the building. However, as a result of the advent of "rated" reflective roofing, the number of roofs that need cleaning may begin to increase dramatically. The reason for this likely increase would be an attempt to maintain effective long-term Solar Reflectance ("reflectance") performance of the roofing surface. It is well known that light- colored roofs get dirty and lose reflectance. The EPA's Energy Star® program allows cleaning of the roof surface before taking the "aged" Solar Reflectance reading. As light colored membranes accumulate dirt, the reflectance value will decrease. Therefore without regular cleaning, a building owner will not fully benefit from the value of roof reflectance. As roofs become soiled and lose their energy savings potential, owners must have a means of deciding if the cost of maintaining a high reflectance roof surface is recovered by the expected energy savings.

In 1998, (SPRI, The Single Ply Roofing Industry), in conjunction with the Oak Ridge National Laboratory (ORNL), began to study the affect of long-term exposure on the reflectance of "commercial" sheet membrane roofs (1). The results, which were reported by Miller, et.al, and presented at the 2004 RCI annual seminar, showed that <u>all</u> sheet membrane products lost reflectance over time (2). The loss occurred in all climate zones and the extent of loss was found to be dependant on the membrane type and exposed surface material. The reflectance loss was significant, ranging from 20% to 55%. The study also found that all of the membranes could be cleaned such that the original reflectance was restored. It, however, did not quantify how often the cleaning should be done. It is generally thought that cleaning the roof every two to three years would be sufficient to keep the time-averaged reflectance from dropping "too far" below the original value.

In southern cooling climates, where reflective roofs can be most effective, the loss of reflectance due to aging or environmental effects substantially reduces the potential energy savings. The important question, then, is, "Can the reflectance of the roofing be effectively restored periodically, at a maintenance cost that will be more than counterbalanced by the savings from reduced energy-use? If there <u>*are*</u> adequate savings, then it makes sense to clean the roofs on the appropriate periodic basis. If it turns out that there are <u>*no*</u> net savings, then alternate means of attaining a satisfactory end result should be investigated and used.

The most efficient and time proven alternative to achieve energy savings is to install additional insulation R-value into the roofing system. The "Long Term Thermal Resistance" (LTTR) R-value for the insulation remains consistent over time, while the long-term performance of reflective roofs drops significantly, and, thus, will require periodic cleaning to maintain an acceptably high reflectance. Indeed, for years, increasing the insulation "R-value" has been the most successful option used in the Midwest and Northern U.S. states, where the "heating energy penalty" significantly counteracts the "cooling energy savings" of highly reflective roofs. Insulation is not only effective in the northern climates. In southern climate zones of the U.S., significant reductions in energy-use can be obtained by using more insulation in the roof system. Somewhat more insulation (but usually not an unreasonable amount) is required in these warmer climates to achieve an affect equal to that in the northern zones. In *all* climate zones, adding insulation reduces *both* heating costs and cooling costs. Three very positive results of adding insulation R-value are that the size of cooling units can be reduced, the need for additional roof maintenance is eliminated, and the overall impact on the environment is lessened.

Using the DOE/ORNL Energy Savings Calculator
The calculator can be found at (http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm.) The table below presents calculated data comparing the effect of adding insulation to the effect of adding roof surface reflectance.

Additional R-Value required to achieve cost savings equivalent to replacing a black roof with a more reflective roof

Starting with an Initial Reflectance of 0.05 and an Initial Insulation R-Value as listed; If the Reflectance is Increased as noted below…		…Then the amount of additional insulation required to achieve equivalent energy performance is (by city):			
Reflectance Increases from:	Initial R-value	Minneapolis CDD = 634 HDD = 8000	Indianapolis CDD = 910 HDD = 5690	Tampa CDD = 3311 HDD = 697	San Diego CDD = 766 HDD = 1075
0.05 to 0.30	15	2.5	0	2.6	2.5
0.05 to 0.55	15	0.2	0.3	10.5	11.3
0.05 to 0.65	15	2	0.4	15	15.2
0.05 to 0.82	15	0.6	0.4	18.1	18.2
0.05 to 0.82	5	0	0.3	7.8	8

Using the DOE/ORNL calculator, replacing a black membrane with a membrane having a higher reflectance will result in summertime energy savings but higher wintertime energy costs. The table above shows that, if a black membrane (reflectance = 0.05) is replaced by a membrane with a reflectance of 0.30, in Indianapolis, the same savings can be achieved by adding zero additional insulation. That's right, in Indianapolis, adding a reflective roof coating will have essentially no affect on average energy savings! If the black membrane is replaced with a new reflective membrane with a reflectance of 0.82, the very same energy savings can be achieved if a small amount of insulation R = 0.4) is added, resulting in a total of R-15.4 in the system. If the black membrane is replaced with a membrane with a reflectance of 0.82 in San Diego, an insulation R-value of 18.2 would need to be added to the system to equal the savings achieved by replacing the black membrane with a membrane having a higher reflectance. Therefore, the San Diego roof with a 0.05 reflectance black membrane would require a total of R = 33.2 insulation to equal the roof having R-15 insulation and a reflectance of 0.82.

The data in the above table demonstrates that, in order to achieve energy savings year-round, adding insulation is a great choice in the colder Midwest and North, and that in sunny, warmer southern climates, adding reflectance and/or insulation R-value can both provide a significant benefit.

Since energy savings is the key reason for installing a high reflectance roof, let's look at what happens to the savings as the reflectance is reduced by soiling of the membrane. San Diego CA is an excellent example, as the use of high reflectance roofs have been encouraged since 2000, and their suggested reflectance values will become the default California Energy Code, aka Title 24, requirement for roofs starting in the fall of 2005. (3)

The data is from the DOE/ORNL Calculator; their calculator uses a baseline reflectance of 0.05 (I.e., assumes a black membrane). In all tables, an emittance of 0.85 is used. The cost of energy, both gas and electricity, is from "Energy User News, Market Place and Data", September 2004. In addition, a Coefficient of Performance (COP) of 2.0 and a gas heating efficiency of 70% are used in all calculations for all tables in this paper.

Using the DOE/ORNL calculator, (see http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm), a roofing system having a sheet membrane roof over an R-15 insulation, an emittance of 0.85, a cooling system with a COP of 2, and a 70% effective heating system, the cooling load savings for a 0.82 reflectance roof, as compared to a black roof, would be $0.072 per square foot per year. After 3 years, the roof will likely have a reflectance of 0.65 or less, and the savings for the system will drop to $0.055 per square foot per year. Should the roof get exceptionally dirty and have a reflectance of 0.41, the savings would only be $0.031 per year.

Example: San Diego CA Cooling Savings (Summer 2004)

Condition	Reflectance	Cooling energy savings per square foot per year vs. a black roof
Initial	0.82	$0.072
20% loss	0.65	$0.055
California Default value	0.55	$0.050
50% loss	0.41	$0.031

If a black roof (reflectance = 0.05) is replaced by a roof with a reflectance of 0.82 in San Diego, the energy savings would be $0.072 per square foot per year. This savings would continue each year that the reflectance remains at the initial value of 0.82. However, it is expected that the membrane will lose reflectivity, and that after the first year the reflectance will be about 0.65. The savings (as compared to the black roof) for the roof with a 20%loss of reflectance (to 0.65), will be about $0.055 per year. That is $0.017 less per square foot per year than if the roof had maintained a consistent 0.82 reflectance. If the minimum cost of cleaning the roof is $0.04 per square foot, the investment in cleaning is not likely to be recovered, because the roof would soil and lose the reflectance restored by the cleaning. If the same roof that started with a reflectance of 0.82 became soiled and had a 50% loss of reflectance (to 0.41), the energy savings as compared to the black roof would be $0.031 per square foot per year. In this case, cleaning the roof and restoring the reflectance to 0.82 would provide an energy savings of $0.041 per year. The building owner would need to balance the cost of periodic cleaning with the potential energy savings.

Another way to determine if there will be value in cleaning a roof is to measure its current (aged) reflectance and compare it to its original reflectance. The reflectance of an in-place roof membrane can be measured using ASTM C1549-02, "Standard Test Method for Determination of Solar Reflectance Near-Ambient Temperature Using a Portable Solar Reflectometer", American Society of Testing and Materials, West Conshohocken, PA, US. This can be done on site with no harm to the membrane. Therefore, if the building's cooling bills are determined to be increasing substantially, it may be worthwhile to remeasure the reflectance of the roof. Knowing the present value of reflectance, and acknowledging that cleaning the membrane can restore the original reflectance, the future cooling energy cost savings from the restored reflectance can be compared to the projected cooling cost savings of the soiled roof. Another important factor is the "cost" of cleaning the roof, which must take into consideration the potential negative effect that it has on roof life and on the environment (due to run off of cleaning chemicals).

In almost all climates there is a "heating penalty" for using a high reflectance roof. A heating penalty occurs when the high reflectance roof keeps the building from absorbing solar energy during the winter heating season. This penalty can be reduced by adding more insulation. Even in San Diego, increased heating costs result from using a highly reflective roof. These increased costs range from $0.004 per square foot per year for a reflectance of 0.82 to $0.002 per square foot per year for a reflectance of 0.41 Heating costs in mild climates are quite limited and the heating penalty may not exist at all for buildings that are highly occupied or have machinery that produces heat.

Of course, heating cost penalties are much greater in climates with significant winter heating or high oil or natural gas costs ($1.03/ Therm). In this study, we will focus on natural gas as the heating fuel. An example of high natural gas costs and significant wintertime heating is Indianapolis IN.

Indianapolis IN, cooling savings and heating penalty

Reflectance	Cooling Savings	Heating Penalty	Net Savings
0.82	$0.031	$0.024	$0.006
0.65	$0.024	$0.018	$0.006
0.30	$0.009	$0.006	$0.003
0.15	$0.005	$0.001	$0.004

Indianapolis (CDD = 910 and HDD = 5690, 2004 fuel gas costs =1.03/therm) is an example of a community with high gas heating costs and relatively low electricity costs. In this case, without a peak demand cost included, energy savings is not a logical reason for installing a high reflectance roof. Energy savings is also not a reason to clean a high reflectance roof in this climate. Changes in the price of electricity or gas can make a big difference in the outcome; so each building should be evaluated based on the actual energy costs. If the building is a large consumer of electricity, demand costs, if applicable, need to be included. This is one situation that may shift the equation to favor a high reflectance roof.

San Francisco CA has high cooling costs and low heating costs, but it only has 69 cooling degree-days. High reflectance roofs have a negative affect in this climate. There is a sizeable heating penalty for adding any reflectance over the default value for the black roof in San Francisco.

Frequency of cleaning

Every time someone is on a roof there is the potential for damaging the roof membrane. This damage can come from many sources. No matter how tough it appears, the roof should not be abused. There is a real probability that high-pressure-washing could damage membrane seams, remove protective surfacing material, or weaken roof/flashing junctions. The Oak Ridge National Laboratory (ORNL) investigation demonstrated that gentle cleaning would remove the soiling, so there should be no need for high-pressure-washing. However, when cleaning roofs, it’s usually much faster to use the higher-pressure washers, especially in areas of greater accumulation; thus there is a great likelihood of their use and, consequently, of potential roof damage. Although membrane suppliers recognize that membranes become soiled, specific recommendations for cleaning are generally absent from their literature and web sites. If cleaning is desired, it is best to contact the membrane supplier and obtain their specific recommendations for frequency and methods of cleaning their products.

Based on the testing from ORNL, membranes typically lose about 20% of their reflectance the first year of service and lose little after the 3rd year. Based on that data, cleaning at the third year is likely to be the most economically viable solution. Further field study is needed to gain a more complete understanding of reflectance loss in “real world” conditions. It may not be economical to clean any membrane that loses less than 25% of its reflectance over its exposed lifetime. “Aged” reflectance values determined by the Cool Roof Rating Council for many products will be available in 2007 -- less than

3 years from now, so a choice can be made at that time to put the average numbers into the DOE program so that building owners can use that value to determine if it's time to clean the roof. Aged values acquired by the CRRC testing will be obtained on materials exposed at a minimum 5% slope, so they will not be exposed to a standing water condition.

At this time, the Energy Star® aged reflectance values now available on the EPA's web site or measured changes in the building's energy consumption can be used to help determine if cleaning is necessary. Most high reflectance roofs will reduce cooling energy usage until they lose a significant amount of their reflectance, but if adequate insulation is in place the need for cleaning can be reduced or eliminated. The insulation R-values supplied by manufacturers today are "LTTR" (Long- Term Thermal Resistance) values, (), and, thus, tend to remain stable over the lifetime of the roof. Because the insulation's R-value can be considered constant, its use is a more effective way to achieve permanent energy savings.

Let's consider the case where a roof is not adequately insulated -- the picture is much different. With a low R-value insulation (R-5), the energy savings from adding a highly reflective roof in a hot climate are substantial – see the example for Tampa Florida below.

Tampa FL. Cooling Savings for a Poorly Insulated Roof (R=5) (E=0.85)

Reflectance	Cooling energy savings per square foot per year
0.82	$0.24
0.65	$0.18
0.55	$0.15
0.45	$0.12
0.30	$0.07

In southern climates where less insulation is typically used, it is likely that a roof having lost 25% or more of its initial reflectance can be economically cleaned. In other words, the cost of cleaning will be exceeded by the value of energy saved. Based on the data above it would be economically feasible to clean a roof membrane yearly. However, as previously discussed, when a roof membrane is subjected to annual cleanings, it may be damaged or its life expectancy decreased. It would be better to add insulation R-value in this case, so that roof cleanings would not be needed as often.

Costs of Cleaning Roofs

Several quotes for cleaning of roofs were obtained from various locations throughout the country. These costs ranged from a low of $0.04 per square foot to a high of $0.75 per square foot. The high cost was from a unionized contractor in an area where there would be little likelihood of any experience cleaning roofs. The low quote was from an area where contractor labor is much less expensive. Building owners have only one recourse, and that is to get several bids from responsible service providers. When considering the cost of cleaning, the environmental requirements of the site and the material must also be considered. There are EPA run-off requirements for all building sites. Before cleaning a roof, those requirements should be reviewed and the cost of achieving compliance included into the quote for the cleaning service.

Long-term performance of high reflectance roofs

It is a fundamental premise of physics that when materials are kept cooler they will deteriorate at a slower rate than materials at a higher temperature. Or simply put, the cooler the material the longer it will last; this applies to virtually all materials. Therefore, a high reflectance thermoplastic membrane may be expected to last longer than a thermoplastic membrane with the same chemical composition with a low reflectance.   In the summer, a clean, light colored membrane will maintain a lower temperature, so its deterioration will be slower. If the membrane's reflectance can be maintained, the life of the membrane may be extended. However there are caveats to keep in mind. There is an increased potential for degrading the product's reflective surface during cleaning and the causing physical damage to the membrane.

We need to sort out the basic longevity of the product itself. Most commercial roofing membranes are expected to last longer than 10 years. Many products have been performing well in the US market for 20 years and longer. An initial choice of reflective material must be made based on the expected life of the roofing membrane. Some reflective products lose reflectance quickly, and to maintain the reflectance, periodic cleaning the roof will be required. The cleaning will regain the anticipated energy cost savings, but may or may not help extend the life of the roof. Data to support the value or cost of cleaning as it relates the longevity of the membrane is needed, but will be slow in developing.

As mentioned previously, for a given roofing product, the higher the its solar reflectance, the longer the roof membrane should survive. This is a *very* generalized statement. The fact is that roof membrane formulations and their reflectance values vary. The formulation of a black roof is very different than the formulation of a white roof. A black roof may last longer than a white roof, or vice versa. There is data showing that adding a high reflectance coating to BUR and Modified Bitumen membrane roofs will extend their life. Using San Diego as an example, the energy savings for coating an R-15 roof would initially save about $0.072 per square foot per year. Considering that cleaning and coating the roof with a quality high-reflectance roof coating system will cost $1.25/ square foot or more; and it will take over 17 years of energy savings to pay for the reflective coating. Therefore, due to the long payback period, extending the roof's life is likely to be the primary reason to add a high reflectance roof to an appropriately insulated roof assembly. In contrast, if the roof in San Diego is poorly insulated (R-5), coating the roof with a reflective material will extend its life and can pay for the cost in energy savings in about 5 years. Good reflective coatings may last 10 years, so there is both an energy savings and a longevity benefit for coating the roof. It is important to remember that results can vary greatly given different circumstances!

Previously in California, there were energy cost rebates for enhancing the reflectance of an existing roof. With the California Title 24 requirements becoming the energy code default requirements in 2005, those rebates are expected to be eliminated.

Regardless of reflectance values, the safe choice is to use products that have a track record of performance in the area in which they are being installed. Environmental benefits of high reflectance roofs energy savings can be totally lost if the system quickly loses reflectance or the system fails and needs to be replaced. Be sure to evaluate the benefits of simply using additional insulation R-value, as that may be the most economical and lowest maintenance route to achieve the energy savings desired. The quality of any roofing system is influenced positively by experienced contractors. Caution and verified performance data are the best defense against potentially expensive roofing mistakes. Professional Registered Roof Consultants are one of the best sources of information on the systems that are performing in the area where the roof is being installed. Most membrane suppliers have trained responsible professionals as well and they should be consulted when available.

References

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