

THE ECONOMICS OF COOL ROOFING: A LOCAL AND REGIONAL APPROACH

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INTRODUCTION

It is now widely acknowledged that highly reflective roofs provide energy cost savings in many areas of the United States. By reducing the effects of solar radiation on building interiors, highly reflective roofs can lower summer cooling loads and, in turn, reduce air conditioning expenses. Research supporting the benefits of reflective roofs includes numerous case studies (Akbari et al., 1997, 1998a; Wilkes et al., 2000; Konopacki and Akbari, 2001) as well as empirical investigations establishing the design parameters of solar radiation control (Wilkes, 1989; Griggs et al., 1989; Petrie et al., 2001). As a result of this research, effective modeling tools have been developed to help building owners and designers make cost-effective decisions regarding roof reflectivity.

Among the tools available to the building owner and designer, the Department of Energy (DOE) Cool Roof Calculator, developed by Oak Ridge National Laboratories (ORNL, 2004), is perhaps the most recognized. This calculator combines climate data for 235 US cities with tested algorithms of energy transfer to provide an accurate assessment of the benefits of reflective roofing almost anywhere in the United States. In addition, the calculator employs a simple Web-based user interface along with extensive supporting information to allow building owners to calculate quickly and easily the potential for energy savings for any building at any location in the country.

Although effective and accurate means of calculating the economic value of reflective roofing are now easily available, some roofing industry leaders have expressed concern that the benefits of reflective roofing may be misunderstood by many building owners and designers. In particular, industry advocates are concerned that building owners and designers may rely on marketing claims and arbitrary performance standards rather than accurate analysis. As stated by Mike Russo (2003), associate publisher and editor of *RSI Magazine*:

The cool roofing trend offers our industry some unique marketing opportunities and a chance to promote itself as a good environmental citizen. But the decisions on where to recommend or require reflective roofs needs to be based on scientific fact, not fiction.

The first area of possible misunderstanding involves the magnitude of savings offered by reflective roofs. Although the Heat Island Group of Lawrence Berkeley National Laboratory (LBNL, 2004) estimates the annual economic benefit of reflective roofing for the billions of square feet of roofs in the United States exceeds \$100 million, the sheer magnitude of this national statistic may inadvertently overstate the individual savings for the average building owner. As an example, while the Heat Island Group advertises that the potential energy savings for all buildings in the City of Chicago exceeds \$10 million annually, the owner of a typical commercial building may see less than \$100 in annual savings (as later demonstrated in this study).

The second area of potential misunderstanding involves the application of generalized reflective roofing principles in areas of the country where solar radiation is not a significant climate factor. Even leading advocates of reflective roofing acknowledge that reflective roofs will have a minimal or even possibly negative impact on energy consumption in some regions of the United States.

Of course, there are areas where reflective roof system summer savings are less than the increased heating costs in the winter. These are cold climates, such as Detroit and Minneapolis, or cloudy areas with cool summers, such as Seattle or San Francisco (Akbari and Bretz, 1998).

Unfortunately, such region-specific caveats may be lost in the homogenization of nationwide standards. As an example, the Energy Star roofing program developed by the Environmental Protection Agency (EPA) recommends a uniform minimum reflectivity standard for all regions in the United States. This establishment of a uniform standard in the face of climatic diversity is further compounded by the lack of an effective disclaimer concerning the use of reflective roofs in cold or cloudy regions of the country. To the building owner inquiring whether “installing an Energy Star qualified roof product will save me money no matter where I live,” the Frequently Asked Questions page of the Energy Star Web site offers the reply that “buildings located in hot and sunny climates will realize the *greatest* energy and cost savings [*italics added*].” (EPA, 2004). Although this statement accurately asserts that the greatest cost savings will be obtained in hot climates, it also inaccurately infers that some amount of savings may be achievable in every area of the country, including very cold and cloudy environments. The LEED Green Building Rating System™ of the US Green Building Council provides another example of how a generalized standard can cause misunderstanding. Although leading authorities caution that reflective roofs may offer minimal or even a negative benefit in cold and cloudy regions, the LEED program awards a “green” credit for a reflective roof regardless of the local climatic suitability.

Misunderstandings due to the lack of effective caveats in programs such as Energy Star and LEED may be further distorted by the marketing messages of commercial organizations with a vested interest in selling reflective roofs. As an example, the Cool Metal Roofing Coalition (CMRC, 2004) states on its Web site that “cool” reflective metal roofs “provide greater energy savings than most other non-metal roofing products on the market today.” Although this assertion may have some validity in a warm and sunny

climate, it is unlikely that a reflective metal roof will provide any more energy savings than any other roof system in a cool and cloudy environment, such as Oregon, or a cold climate region, such as Minnesota.

STUDY OBJECTIVE

Although building owners and designers now have access to effective tools, such as the Cool Roof Calculator, to measure the benefits of reflective roofing, they are also bombarded with simplistic messages that may deter them from using these tools. As a consequence, building owners and designers may benefit from the development of a simple, unified graphic representation showing how various local factors may affect the potential energy savings of reflective roofs. Such a representation would be especially useful if the unit of the measurement were more aligned to the scale of individual buildings rather than entire communities. The usefulness of the chart may be further enhanced by using the most recent available information on energy costs for many different locations across the United States. This would be particularly useful since local energy costs may vary by as much as 300% throughout the country (as documented in Table 1).

This study will develop two graphic representations of the geographic variation in reflective roofing energy savings. The first will be a simple tabular representation of the energy data for over 40 cities in the United States. This chart will allow direct comparison of the key input variables and calculated outputs for each location. The second graphic representation will be a map of the United States dividing the cities into common geographic bands representing different increments of energy savings.

METHODOLOGY

Using the DOE Cool Roof Calculator, net energy cost savings for a reflective roof versus a non-reflective roof were calculated for identical low-slope commercial buildings located in 40 cities across the United States, as listed in Table 1. Net cost savings for each building were based on the following inputs.

1. Local Climate Conditions. The total heating degree days, cooling degree days, and solar loads for each location were based on current inputs from the Cool Roof Calculator. It should be noted that these climatic inputs have been validated extensively by Oak Ridge National Laboratories (Petrie et al., 2001).
2. Local Energy Costs.
 - a. Electricity for Cooling. Cooling costs were derived from Energy Information Administration data (EIA, 2004a) for commercial electricity prices by state for the month of June 2004.
 - b. Natural Gas for Heating. Cooling costs were derived from Energy Information Administration data (EIA 2004b) for commercial natural gas prices by state for the month of June 2004.
3. Roof Reflectance and Emittance. The solar reflectance value for the reflective roof was held constant at 55% for all locations. This value was based on best available information regarding the aged value of reflective roofs, as

investigated by Akbari et al. (1998b) and Petrie et al. (2001). In addition, the 55% value is currently used as the calculation value for reflective roofs in ASHRAE 90.1 Energy Standards for Buildings (ASHRAE, 2001). The reflectance value of the non-reflective roof was held constant at 5%, which is the default value in the Cool Roof Calculator for an uncoated asphalt roof surface. The infrared emittance for both the reflective and non-reflective roofs was held constant at 80%, which is a typical value for most non-metallic flat roof systems.

4. Heating and Cooling System Efficiency. Cooling system efficiency was held constant at a coefficient of performance (COP) of 2.0 and heating system efficiency was held at 70%, both of which are the “average” values as recommended by the Cool Roof Calculator.
5. Roof System R-Value. The insulation R-value of the roof was held constant at R=20, which is very close to the ASHRAE 90.1 average recommended R-value for most areas of the country.
6. Roof System Size. The size of the roof system was assumed to be 20 000 square feet. This size was derived from a survey of a major roofing manufacturer’s roof warranty database of commercial roofing installations throughout the United States (Hoff, 1997). With two billion square feet of roof surface distributed among approximately 100 000 individual roofs in this database, it would appear reasonable to assume that the average size of a typical commercial roof installation in this country is very close to 20 000 square feet.

RESULTS

Regional Distribution of Energy Savings

As shown in Table 1, the calculated annual energy savings for a reflective versus a non-reflective roof installed on a 20 000 square foot building varied from a high of \$860 in Phoenix, AZ, to a net loss of \$100 in Seattle, WA. In general, these variations in savings appeared to align geographically, with the greatest savings occurring in the southern and western United States and the least savings in the north.

To better illustrate the geographic relationship to energy savings, the results for all 41 cities were plotted on a map of the United States and assigned to geographic bands of \$100 savings increments, as shown in Figure 1. A total of six savings bands were plotted, ranging from a low of a negative savings of -\$100 to a high of \$500 or more. In the northernmost band, energy savings were either non-existent or negative. This band included many areas of the country generally assumed to have cold winter climates (e.g., Detroit, MI, Milwaukee, WI and Minneapolis, MN) or cool, cloudy summer climates (e.g., Portland, OR and Seattle, WA). Several other major urban areas, including Chicago, IL and Cleveland, OH, with \$20 net savings each, lie very close to this band.

The next adjacent band below the area of negative savings includes a large area of the country where the benefits of reflective roofs appear to be fairly minimal, at less than \$100 annually for a typical 20 000 square foot building. This area appears to cover large portions of the mid-west down to the Ohio Valley as well as some portions of the

Western US, including areas of significant population, such as Boulder (Denver), CO and Reno, NV.

The next two adjacent bands identify another large area of the country where reflective roofs begin to offer more significant energy savings of \$200 to \$400. This area appears to cover most of the southeast United States as well as portions of the lower mid-west and southern California. Finally, even larger annual energy savings, ranging from \$500 to almost \$800 can be identified in the southernmost band consisting of the extreme southeast United States as well as the desert southwest.

Effect of Local Energy Prices

The interaction between climate and energy cost can be analyzed by looking at apparent savings discrepancies between some cities with similar climatic factors. As an example, although New York City and Salt Lake City, UT have a very similar number of heating and cooling degree days, the annual energy savings provided by a reflective roof in New York is almost twice the savings in Salt Lake City, even though Salt Lake City experiences a 16% higher solar heat load. This apparent discrepancy is due to a significant difference in local electricity pricing between the two cities, with the price of electricity over 80% higher in New York than Salt Lake City. A similar situation can be observed between Baltimore, MD and Richmond, VA. Although both cities share a very similar climate, reflective roof savings are higher in Baltimore primarily because the electricity price is over 60% higher.

Effect of Higher Reflectivity Levels

As mentioned previously, the calculations shown in Table 1 were based on a reflectance of 55% for the reflective roof. When reflectance is increased to 70%, the effect on energy savings appears to vary by geographic band. In the upper band of Figure 1, where a reflective roof may actually increase energy costs, increasing the reflectance to 70% only magnifies the negative impact. As an example, a \$100 energy loss in Seattle with a 55% reflective roof rises to a \$160 loss with a 70% reflective roof. In the next adjacent geographic band where energy savings are relatively minimal to start with, any increase in roof reflectivity has little effect, either positive or negative. As an example, the base case savings of \$60 in Indianapolis, IN, remains unchanged when roof reflectance is increased to 70%.

In the next two geographic bands covering most of the southeast and lower mid-west, increasing roof reflectance to 70% produces a moderate increase in energy savings. As an example, the base case savings of \$260 in Charlotte, NC increases to \$340 when reflectance is increased. Finally, in the southernmost geographic band, increasing roof reflectance produces a relatively significant increase in energy savings. As an example, in Phoenix, AZ, annual energy savings rise from \$860 to \$1,160 when roof reflectivity is raised from 55% to 70%.

DISCUSSION

Reflective Roofs and the Building Owner

Perhaps the most significant observation that may be derived from this analysis is that the energy savings provided by a reflective roof may offer little economic incentive for the average building owner in many areas of the United States. Of course, in cold and cloudy regions of the country where reflective roofs may actually increase energy costs, an informed building owner would clearly have little economic incentive to select a reflective roof. And in major mid-west cities, such as Chicago, Cleveland and Pittsburgh, where reflective roofs offer minimal annual savings of \$20 to \$60, it is difficult to see how such small savings will affect the purchase decision of an informed building owner.

In warmer areas of the country such as the upper southeast and mid-Atlantic, it is possible that annual savings in the range of \$200 to \$400 for a 20 000 square foot roof may exert some influence on purchasing decisions. However, the real value of such savings may still be very small in comparison to the overall purchase price of a roofing system. As an example, a new 20 000 square foot commercial roof system may cost between \$80,000 and \$120,000, while 10 years of \$400 annual energy savings may amount to less than 3% of the original purchase price, when calculated at present dollar value. Although it certainly is possible that a reflective roof may be selected over a similarly priced non-reflective roof, such low levels of potential savings may make it difficult for a reflective roof to command any price premium.

Even in areas of the country where the energy savings provided by reflective roofs becomes sizeable, some economic problems still must be addressed. Although annual energy cost savings in excess of \$500 may certainly provide an incentive for the owner of a typical 20 000 square foot commercial building to select a reflective roof system for an initial roof installation, the amount of annual savings may not be adequate to justify the application of reflective coatings to an existing non-reflective roof surface. Assuming the cost of a commercial-grade roof coating applied to a 20 000 square foot roof will be approximately \$10,000 (or \$0.50 per square foot), the payback period for even \$1,000 annual energy savings will be in excess of 10 years.

LIMITATIONS OF THE STUDY

Electricity and Natural Gas Pricing

Although energy prices used in the study are assumed to be constant, many areas of the country experience significant price spikes at certain times of the year. In areas where air conditioning demand is high in the summer, building owners may have to pay additional peak demand charges above and beyond base rates. Likewise, in areas of the country where the demand for heating fuel is high in the winter, local price spikes and surcharges may significantly increase natural gas prices during the heating season. In addition, EIA data by state may not accurately represent energy costs for each specific city selected for the study. Any building owner or designer interested in the potential energy savings for a reflective roof should thoroughly investigate local energy pricing dynamics and rate structures.

Calculator Validity

Although the DOE Cool Roof Calculator is recognized as one of the best available resources for analyzing the economics of a reflective roofs, other calculators are available

that may provide different results with the same inputs. As an example, the EPA Energy Star web site offers a similar calculator that typically generates higher amounts of savings compared to the DOE Calculator. At the time this paper is being written, the author is aware that representatives of DOE and EPA are seeking to resolve this issue in an effort to provide the public with a single, validated method of calculation. Until a single calculation model is established, building owners and designers should seek information from a variety of sources, including local energy consultants.

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Table 1
Annual Energy Cost Savings: Reflective Windows-Reflective Roof
 (2010 to 2019) (Building Energy Modeling Software)

City	State	Level Energy Costs		Level Climate Conditions			Calculated Annual Savings
		Reflectivity (\$/sq ft)	Roof Color (kWh/m ²)	Heating (Degree Days)	Cooling (Degree Days)	Annual Energy Use (kWh)	
Albuquerque	NM	\$0.071	\$1.137	3329	1371	1429	\$57
Albuquerque	NM	\$0.071	\$1.137	3191	1428	1411	\$57
Phoenix	AZ	\$0.073	\$1.068	1129	2312	1036	\$11
Los Angeles	CA	\$0.125	\$0.700	1281	470	1375	\$10
San Francisco	CA	\$0.125	\$0.780	3230	30	1330	(\$40)
Portland	OR	\$0.059	\$1.609	4717	627	1437	\$40
Denver	CO	\$0.049	\$1.119	1711	3127	1557	\$57
Denver	CO	\$0.049	\$1.119	1697	3171	1521	\$11
Jacksonville	FL	\$0.079	\$1.170	1427	2227	1430	\$10
Atlanta	GA	\$0.051	\$1.250	3000	1511	1475	\$28
Baltimore	MD	\$0.050	\$1.677	4707	627	1414	\$10
Chicago	IL	\$0.051	\$1.181	4729	175	1390	\$10
Chattanooga	TN	\$0.023	\$1.138	3281	810	1377	\$10
Louisville	KY	\$0.020	\$1.078	4441	1000	1327	\$12
New Orleans	LA	\$0.052	\$0.690	1454	2530	1430	\$12
Portland	ME	\$0.115	\$1.077	7447	315	1387	(\$50)
Baltimore	MD	\$0.047	\$1.677	4717	1127	1387	\$27
Boston	MA	\$0.110	\$1.631	4311	671	1210	\$11
Detroit	MI	\$0.019	\$1.561	4725	527	1211	\$1
Minneapolis	MN	\$0.050	\$0.854	6000	634	1287	\$0
Kansas City	MO	\$0.055	\$1.127	4127	1447	1337	\$17
St. Louis	MO	\$0.055	\$1.127	4721	1727	1315	\$17
Greenville	SC	\$0.023	\$1.281	3715	1575	1211	\$21
Omaha	NE	\$0.010	\$1.121	4325	1321	1317	\$12
Las Vegas	NV	\$0.027	\$0.6070	2230	2227	1400	\$10
Prato	GA	\$0.023	\$1.687	4727	334	1327	\$10
Albuquerque	NM	\$0.070	\$1.147	4331	1271	1327	\$17
New York City	NY	\$0.128	\$1.571	4381	1325	1238	\$21
Cleveland	OH	\$0.019	\$1.527	4127	671	1111	\$10
Madison City	IN	\$0.020	\$1.030	3000	1310	1330	\$10
Portland	OR	\$0.051	\$1.687	4651	327	1127	(\$50)
Pittsburgh	PA	\$0.024	\$1.107	4727	634	1327	\$10
Portland	ME	\$0.028	\$1.588	4325	1575	1210	\$21
Fort Worth	TX	\$0.059	\$1.061	2321	2710	1328	\$11
Houston	TX	\$0.059	\$0.690	1328	2310	1430	\$10
Salt Lake City	UT	\$0.056	\$0.7240	6538	1254	1475	\$16
Portland	OR	\$0.055	\$1.107	4727	1227	1327	\$17
Seattle	WA	\$0.055	\$1.281	4527	177	1317	\$110
Minneapolis	MN	\$0.010	\$1.561	4721	527	1215	(\$21)
Chattanooga	TN	\$0.021	\$0.600	2230	220	1410	(\$10)

1. Calculations conducted using DOE Cool Roof Database (http://www.energycodes.gov/coolroofs/coolroofs.cfm) and EnergyPlus
 2. Reflectivity: Reflectance of 0.85 (dark) and 0.90 (light) for dark and light colors
 3. Heating system: Energy source: natural gas; cooling system: electric; air conditioning system: electric
 4. Energy costs based on commercial rates by state as reported by the Energy Information Administration for the month of June, 2011.

