Special Feature: Reflective Roofs

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Photos: (left) NationalCoatings.com; (right) CommercialRoof.com.

For nearly two decades, the U.S Environmental Protection Agency's (EPA) ENERGY STAR® program has labeled white roofing materials as an energy efficient means to reduce cooling costs through solar reflectance. As a result, the use of white roofing materials has proliferated in a variety of climate zones across the United States, but are these materials delivering on their energy efficient promise? Does it make sense to label one component of a roofing system "energy efficient" when a complete system design is required for true energy efficiency?

Some experts say no, as new studies reveal efficiency losses and other complications for white roof applications, especially in northern climates where heating costs far outweigh cooling costs. The test of time for white roofing is producing mixed results; energy efficient roof color is vastly dependent upon climate, building use, energy costs, and roof system design.

It's a fact. White roofs can save cooling costs. During the cooling season, white roofing materials reflect ultraviolet and infrared radiation in the form of heat away from a building, requiring less energy expenditure to cool the building. In Miami, for instance, the loss of reflected heat from a white roofing surface during the heating season is minimal and is easily outweighed by the savings gained from reflected heat during the cooling season. When accounting for both cooling and heating demands, white roofing material is a logical choice in a hot climate and location like Florida.

But what effect does white roofing material have on energy efficiency during the cooling and heating seasons in cold, northern climates?

A Black And White Issue

Travel north to Boston and the climate and location tell a different story for white roofs. There, the length of the cooling season is significantly shorter and the heating season is significantly longer than in Florida. A white roof installation in Boston would provide small cooling efficiencies during the cooling months and large losses in heating efficiency during the heating months. A white roof would reflect heat away from the building year round, causing an increase in heating costs and a net increase in energy demand over the course of the year. With white roof materials, energy costs in northern climates can actually increase—a fact not clearly reflected in the ENERGY STAR labels on reflective roofing materials.

According to the U.S. Department of Energy (DOE) Buildings Energy Data Book[1], heating costs in northern climates are typically three to five times greater than cooling costs. ENERGY STAR recommends using the DOE's Roof Savings Calculator[2], to determine the net annual impact of white roofing material on both heating and cooling costs before assuming a white roof will save energy costs.

Table 1: Roof Savings Calculator (ORNL/LBNL)

Comparison of Black vs. White roof color for the 25 most populated U.S. Cities in colder climates

City	Cooling Benefit w/White	Heating Penalty w/White	Net Annual Impact w/White	Energy Efficient Color	Electric Cooling Rate cents/kWh	Gas Heating Rate $/1000 ft3
New York City, NY	$163	($515)	($352)	Black	15.11	8.32
Chicago, IL	$115	($431)	($316)	Black	8.07	7.04
Philadelphia, PA	$165	($556)	($391)	Black	9.33	9.87
Indianapolis, IN	$133	($483)	($350)	Black	9.14	7.29
San Francisco, CA	$88	($738)	($650)	Black	16.94	8.46
Columbus, OH	$152	($434)	($282)	Black	9.41	7.14
Charlotte, NC	$231	($458)	($227)	Black	8.73	9.79
Detroit, MI	$123	($480)	($357)	Black	10.95	7.51
Boston, MA	**$173**	**($673)**	**($500)**	**Black**	**14.14**	**11.44**
Seattle, WA	$63	($509)	($446)	Black	7.69	9.11
Denver, CO	$173	($447)	($274)	Black	9.42	6.84
Washington, DC	$223	($644)	($421)	Black	11.95	12.02
Nashville, TN	**$264**	**($398)**	**($134)**	**Black**	**10.26**	**7.65**
Baltimore, MD	$194	($498)	($304)	Black	10.43	9.3
Louisville, KY	$202	($357)	($155)	Black	8.72	7.02
Portland, OR	$84	($685)	($601)	Black	8.36	8.96
Milwaukee, WI	$89	($517)	($428)	Black	10.57	7.05
Kansas City, MO	$187	($389)	($202)	Black	9.2	8.17
Virginia Beach, VA	$188	($404)	($216)	Black	8.06	8.21
Colorado Springs, CO	$127	($522)	($395)	Black	9.42	6.84
Raleigh, NC	$264	($471)	($207)	Black	8.73	9.79
Omaha, NE	$126	($427)	($301)	Black	8.4	6.33
Oakland, CA	$88	($738)	($650)	Black	16.94	8.46
Minneapolis, MN	$79	($441)	($362)	Black	8.95	6.48
Cleveland, OH	$151	($386)	($235)	Black	9.41	7.14

Assumptions: 10,000 square foot, one story building; 40% window-to-wall ratio; post-1990 construction; mid-efficiency heating and cooling equipment; R-20 insulation with gas heat. Aged reflectance: Black EPDM=9, White=70. Aged emittance: Black EPDM=84, White=86.

Using this calculator, a cost comparison table (seen above) was created that shows black versus white roofing materials for the 25 most populated U.S. cities in colder climate zones. The sample data for a fairly common building design demonstrate the net annual impact in energy costs where R-20 insulation and gas heat are assumed for a one story, 10,000 square foot building; with a 40% window-to-wall ratio, post-1990 construction, and mid-efficiency heating and cooling equipment. A review of the calculations affirms why the distinction between heating and cooling demands must be considered.

Using these specifications, the comparison shows a northern climate and location such as Boston would experience a $173 savings in cooling costs where white roofing is used, and incur a $673 heating penalty due to reflected heat during the heating season. The net result is $500 in additional energy expenditures with white roofing material. Thus, the energy efficient color for Boston is black.

Pierce is the owner and President of Foothills Roof Services, Inc. in Larkspur, CO and has been involved in the roofing industry since 1980. He has been a member of the Roof Consultants Institute (RCI) since 1996, from which he earned his RRO certification in 1999.

Perhaps the most surprising city in this comparison is Nashville, TN. It might be assumed that a southern location would naturally dictate use of white roofing material, but even locations this far south can benefit from black roofing. The net annual impact is much smaller, $134, but nonetheless still demonstrates a building in Nashville would experience greater overall efficiency from a dark or black roof than from a white roof in this scenario.

In order to select the best roofing materials, facility managers must consider components that meet the needs of building design, location, and climate conditions.

And the industry could benefit from a re-examination of ENERGY STAR's labeling practices; at a minimum, ENERGY STAR could include the same clarifications that can be found on its website. The site refers users to the DOE's Roof Savings Calculator and also states: "Please remember the energy savings that can be achieved with reflective roofing is highly dependent on facility design, insulation used, climatic conditions, building location, and building envelope efficiency." Most importantly, ENERGY STAR could drop the single component approach altogether. The program excels in the appliance industry because the EPA evaluates a finished product. Likewise, a roof should be evaluated by the sum of its parts, not by a single component, as many components factor into an efficient and effective roof assembly.

References:

[1] Buildings Energy Data Book. (n.d.) Buildings Energy Data Book. Retrieved December 9, 2013, from http://buildingsdatabook.eren.doe.gov/

[2] Roof Savings Calculator (RSC) – DOE ORNL LBNL CEC EPA. (n.d.). Roof Savings Calculator (RSC) – DOE ORNL LBNL CEC EPA. Retrieved December 9, 2013, from http://rsc.ornl.gov/

Editor's Note: *On August 20, 2014, Oak Ridge National Laboratory (ORNL) posted the following note on its site where the Roof Savings Calculator is located, "The Roof Savings Calculator (RSC) is undergoing revision and validation. Results from the current version of RSC (beta release 0.92) may be inaccurate and should not be cited."* TFM *is following up with ORNL to report on the developments.*

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