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Separating Cool Roofing Facts From Myths

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Presented by: Chemical Fabrics and Film Association Inc.
1300 Sumner Ave.
Cleveland, OH 44115-2851

Description: White roofs made of vinyl can reflect three-quarters or more of the sun's rays and emit 70% or more of the solar radiation absorbed by the building envelope. Despite protecting and keeping buildings cool in all climates around the world for decades, misconceptions about the energy impact of cool roofs still exist. This course uses the fundamental science behind cool roofs to address alleged issues concerning the performance of cool roof products.

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Purpose and Learning Objectives

Purpose:

White roofs made of vinyl can reflect three-quarters or more of the sun's rays and emit 70% or more of the solar radiation absorbed by the building envelope. Despite protecting and keeping buildings cool in all climates around the world for decades, misconceptions about the energy impact of cool roofs still exist. This course uses the fundamental science behind cool roofs to address alleged issues concerning the performance of cool roof products.

Learning Objectives:

At the end of this program, participants will be able to:

- explain the concept of "cool roofing," describe how cool roofs function, and state how they are defined and qualified in various energy and environmental codes and standards
- assess the potential environmental impacts of broad implementation of cool roofing strategies
- evaluate the energy benefits of cool roofing materials in northern climates
- cite case studies to show how cool roofs offer both immediate and long-term savings in building energy costs, and
- review the performance of some cool roofing materials in practice over the past decades.

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An Introduction to Cool Roofing

Introduction

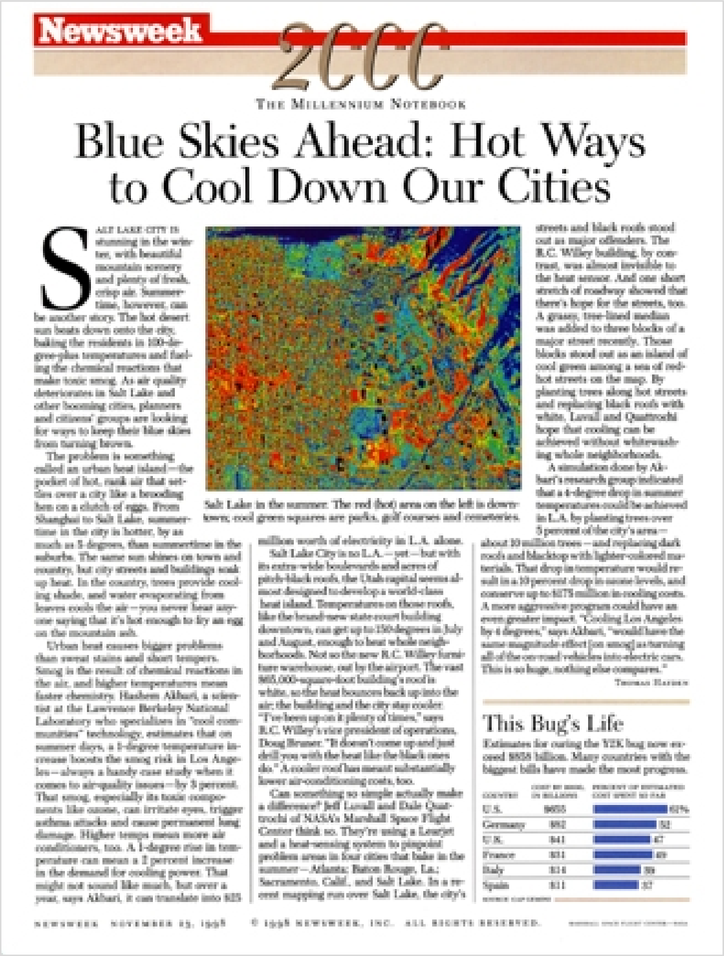
The concept of “cool” construction materials is not new. From the earliest of times, mankind in hot climates understood that making their homes and buildings white made them cooler and more comfortable.

White buildings in Santorini, Greece

Cool Roofs: Scientific Recognition

Scientific recognition of the potential benefits of cool roofs started in the 1990s.

One of the first references to them in mainstream media was in *Newsweek* magazine's millennium edition, which was published in November 1998.



Newsweek 2000

THE MILLENNIUM NOTEBOOK

Blue Skies Ahead: Hot Ways to Cool Down Our Cities

This Bug's Life

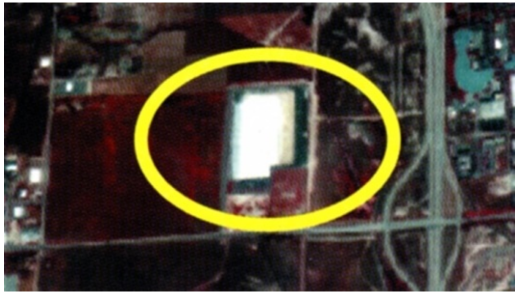
R.C. Willey Distribution Center, Salt Lake City, Utah

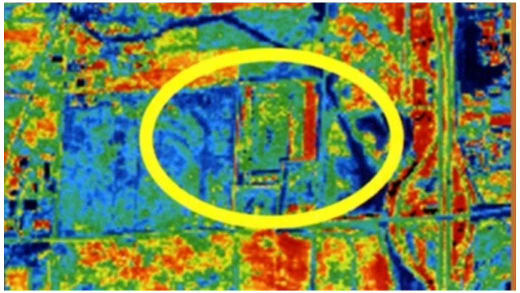
The *Newsweek* article highlighted the R.C. Willey Distribution Center, a large building featuring a 285,000-square-foot roof covered with a light-colored thermoplastic PVC membrane (top image).

Being such a large building, it is clearly visible in the aerial view photograph taken from NASA's Global Hydrology and Climate Center (middle image).

In the lower thermal infrared image, the building (the green rectangle in the center of the yellow circle) tends to blend in with the non-paved surroundings. Unlike the parking lot—which is clearly visible in red, indicating it is much hotter than the surroundings—the roof of the R.C. Willey Distribution Center is similar in temperature to the ground around the building.

R.C. Willey Distribution Center





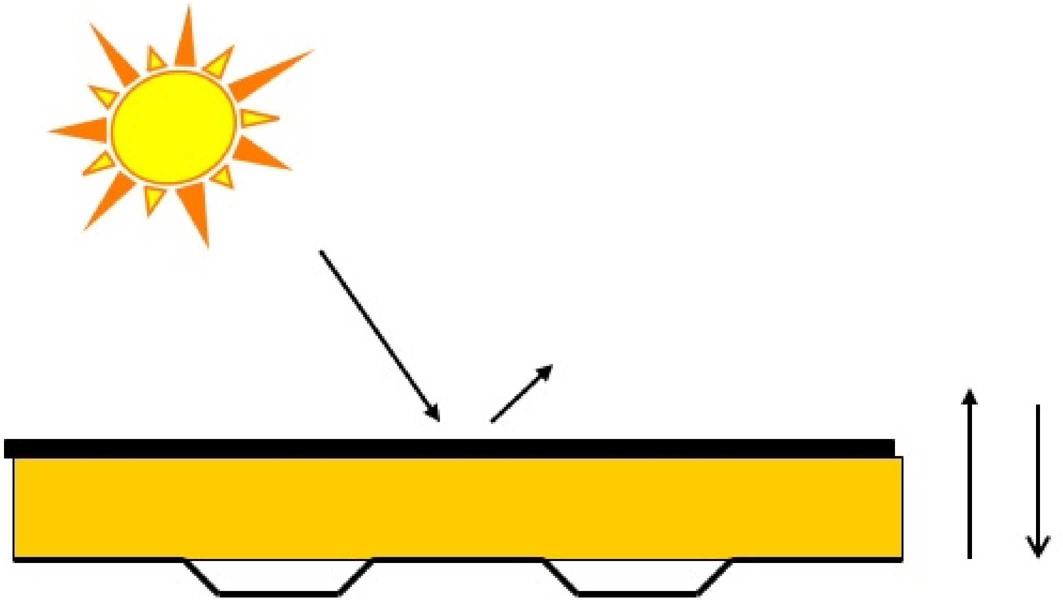
Roofs & Heat Flow

So, how does a cool roof work to lower roof surface temperatures?

To answer that question, we will begin with a discussion of roofs and heat flow.

Heat moves across building envelopes, including roofing assemblies, both inward and outward of the building.

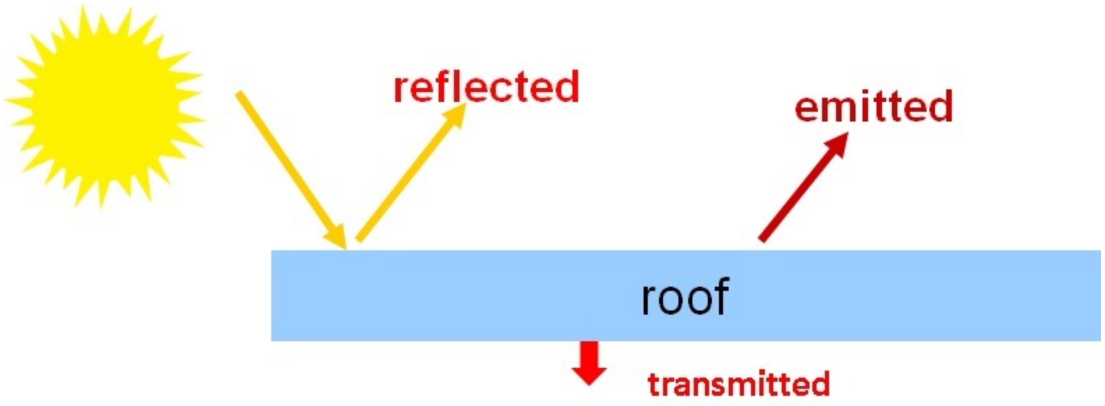
The most important source of heat from the outside is the sun warming up the surface of the roof. Some of the sun's energy reflects off the roof's surface back into the atmosphere, while some of it is absorbed, ultimately contributing to heating up the enclosure.



Solar Reflectivity, Emissivity, & Solar Reflectance Index

The key properties related to the effects of solar energy acting on roofing surfaces include:

- solar reflectivity
- emissivity, and
- solar reflectance index.



Solar Reflectivity, Emissivity, & Solar Reflectance Index

Solar reflectivity refers to the amount of the incoming solar energy a material reflects back into the atmosphere. It is also known as “albedo,” and it is usually expressed as a percentage. Roofing membranes are available with a reflectivity level of roughly 83%, meaning 83% of the solar energy that strikes the membrane is reflected back into the environment. The balance of the energy that does not get reflected will be absorbed by the roof. Part of that energy will be transmitted into the structure, while some of it will be emitted back to the environment.

Emissivity refers to the amount of energy a material releases that it has absorbed, and it is also typically expressed as a percentage. The higher the reflectivity and the higher the emissivity, the “cooler” the roofing material is. However, it is difficult to assess and compare roofing materials based on two different metrics or properties. Which property is most important? How do you trade them off?

The answer to that is solar reflectance index (SRI), a calculation that takes into account both reflectivity and emissivity, combining them into a single number, which makes it much easier to assess and to compare roofing materials.

Characteristics of Common Roofing Materials

The solar reflectance properties of some common roofing materials are shown in this table. At one end of the scale, EPDM has a low reflectivity of roughly 6%. At the high end, white thermoplastic membranes, such as PVC, typically have a solar reflectance in excess of 80%. All materials listed have similar levels of emittance, ranging in percentages from the high 80s to low 90s. The SRI of the materials is displayed in the last column. EPDM and smooth bitumen are at the low end (-1), while white thermoplastic surpasses the other materials with an SRI of 104.

Material	Solar Reflectance	Emittance	Solar Reflectance Index
Black EPDM	0.06 (6%)	0.86 (86%)	-1
Smooth Bitumen	0.06 (6%)	0.86 (86%)	-1
White Granular Surface Bitumen	0.26 (26%)	0.92 (92%)	28
Dark Gravel on BUR	0.12 (12%)	0.9 (90%)	9
Light Gravel on BUR	0.34 (34%)	0.9 (90%)	37
White Thermoplastic (Vinyl)	0.83 (83%)	0.92 (92%)	104

Source: Cool Roofing Materials Database. Lawrence Berkeley National Laboratory, 2000.

Programs That Define Cool Roofing

The definition of a cool roof varies between different green building programs.

- The most common, and probably the best known, program is ENERGY STAR®, which defines cool roofs as materials with an initial reflectivity of 65%, and an aged reflectivity of 50%. They do not have any requirements for emittance.
- Green Globes™ calls for an initial reflectivity of 65%, emissivity of 90%, or an SRI of 78. To be in compliance with their requirements, a material must meet both reflectivity and emissivity values, or the SRI.
- California's Title 24 now calls for aged reflectivity values. In order to meet Title 24 prescriptive requirements, materials must have an aged reflectivity of at least 63% and emittance of at least 75%, or an aged SRI of 75.
- The LEED® green building certification program calls for a minimum SRI of 78 based on initial values; ASHRAE has the same requirement.

The table on the following slide summarizes the information on this slide.

Programs That Define Cool Roofing

		Solar Reflectance	Emittance	Solar Reflectance Index
ENERGY STAR®	Low slope[1] Initial Aged[2]	 0.65 (65%) 0.50 (50%)		
Green Globes™	Initial	0.65 (65%)	0.90 (90%)	78 [3]
California Title 24	Low slope Aged [2]	0.63 (63%)	0.75 (75%)	75 [4]
USGBC LEED green building certification program	Low slope, initial			78 [3] (min 75% of roof)
ASHRAE Standard 189.1	Low slope			78 (min. 75% of roof)

[1]A roof surface having a maximum slope of 2 inches rise for 12 inches run.

[2]Three years' exposure.

[3]Roughly equivalent to, for example, 0.65 (65%) reflectance and 0.90 (90%) thermal emittance, although a number of different combinations of reflectance and emittance can achieve this value.

[4]May not apply in every climate zone.

Cool Roofing Regulations

Numerous cities have implemented cool roofing regulations. Intuitively, we tend to think of cities in the South with hot, humid climates doing this, but many cities located in northern locations have also legislated cool roofing codes and bylaws, such as New York City, Chicago, and Toronto.

The Cool Roof Rating Council (CRRC) maintains a database of solar reflectance and emittance values of roofing materials tested and weathered according to the CRRC's clearly defined policies and procedures. The database can be accessed on the CRRC website at www.coolroofs.org (Accessed January 2017).

New York City Building Code (2008)	City of Chicago Energy Conservation Code (2009)	City of Toronto Green Roof Bylaw
New construction, slope < 3/12	New residential and commercial, slope < 2/12	New industrial buildings
ENERGY STAR rated, covering at least 75% of area	$\text{Reflectance}_{initial} > 0.72$ $\text{Reflectance}_{aged} > 0.50$	Vegetated roof or cool roof
	CRRC or ENERGY STAR listed	

Benefits of Cool Roofing

Principle Benefits of Cool Roofing

Two key benefits associated with cool roofs are a reduction in:

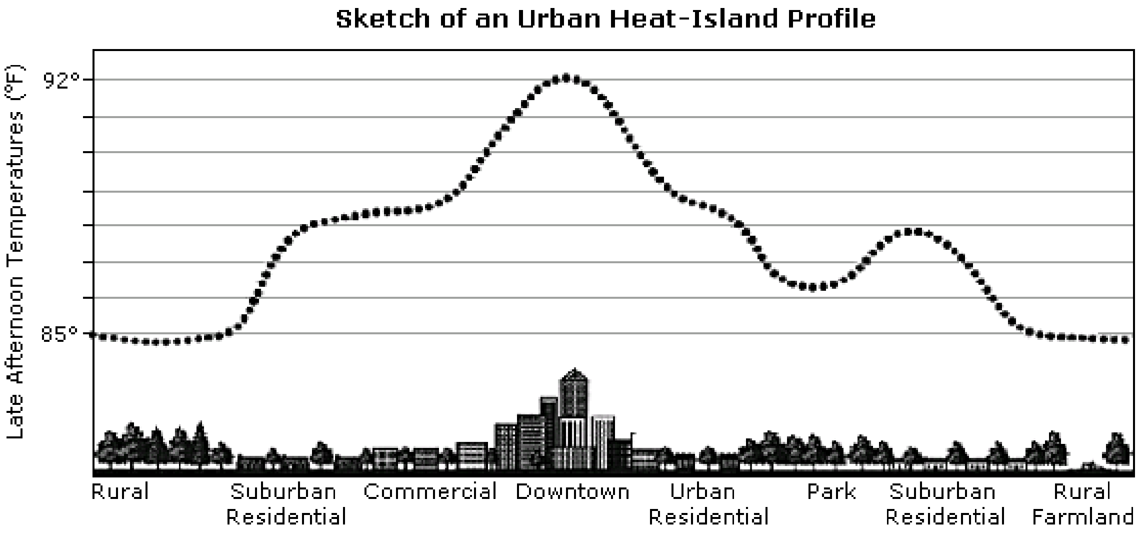
- the urban heat island effect (UHIE), and
- cooling energy consumption.

This course will review both benefits in detail, beginning with a discussion about the urban heat island effect.

Urban Heat Island Effect

The urban heat island effect results from the concentration of dark surfaces, such as dark roofs and asphalt paving (parking lots, roads, etc.) in cities and large urban areas that absorb energy from the sun, which ultimately heats up the entire area. The net effect is that cities are a few degrees hotter, typically 2°F to 5°F, than the surrounding rural areas.

The urban heat island effect occurs in all climate zones. We have all probably experienced the cooling effect of leaving a city on a hot summer Friday afternoon…



Impacts of Reducing the Urban Heat Island Effect

One of the most significant byproducts of the urban heat island effect is smog formation. The hotter a city gets, the greater the amount of smog formed. Reducing the urban heat island effect can contribute to a reduction in smog in our cities.

We will discuss the building-specific energy impacts of cool roofs shortly. However, collectively, broad implementation of technologies such as cool roofing and cool paving results in overall cooling and a reduction in greenhouse gas emissions. This is due to reduced power generation resulting from lower cooling demands on buildings.

Lawrence Berkeley National Laboratory estimates that if cool roofs were installed on 80% of American conditioned roof areas, that is any area that is heated and cooled, it could result in annual CO_2 reductions of 6.23 megatons. To put that into context, that would be the equivalent of offsetting the CO_2 emitted by 1.2 million cars.

Source: Levinson, R. and H. Akbari. "Potential Benefits of Cool Roofs on Commercial Buildings: Conserving Energy, Saving Money, and Reducing Emission of Greenhouse Gases and Air Pollutants." *Energy Efficiency*, 3(1), 53-109, 2010.

Global Perspective

From a global perspective, Lawrence Berkeley National Laboratory estimates that if the cool roofing and paving strategies were implemented around the world, the result would be equivalent to a one-time reduction of 44 gigatons, or 44 billion tons, of CO_2 emissions.

In subsequent slides, the allegations and facts surrounding the benefits of cool roofing, beginning with its effectiveness in reducing global warming, are discussed.

Global Warming Reduction

Allegation:

A Stanford University study contends that white roofs may reduce temperatures locally, but may or may not reduce overall global warming.

Fact:

Most of those quoting the results fail to note that the Stanford report clearly highlights that the uncertainty range with their data is very high. Therefore, their conclusions must be evaluated in the appropriate context.

Conversely, research was done independently at the University of Perugia in Italy, as well as at the National Center for Atmospheric Research (NCAR) in America. The work done at both institutions concludes that Lawrence Berkeley's estimates of CO_2 reductions are actually conservative—that the benefits are likely even greater than their calculations.

Cool Roofing & Energy Savings

Cool Roofing & Energy Savings: First Field Study

The first field study of cool roofs was done on a Target retail store in Austin, Texas in 2001 and funded by the U.S. Department of Energy (DOE) and U.S. Environmental Protection Agency (EPA).

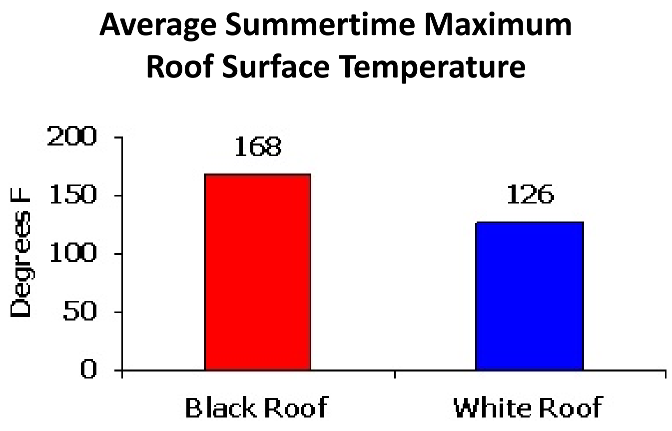
A typical Target store of approximately 100,000 square feet with a black EPDM roof was used for the study. The researchers instrumented the roof and the building to monitor the temperatures at three locations: at the roof level, within the insulation, and inside the building. The energy consumption was also monitored. After accumulating their data, they replaced the black EPDM membrane with a white reflective thermoplastic PVC membrane, and monitored the temperatures and energy consumption.

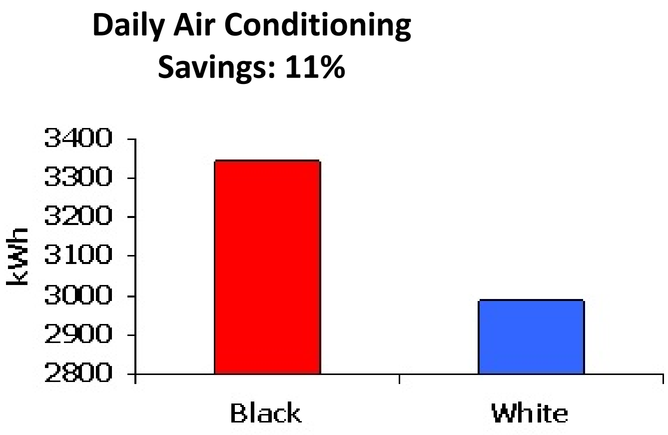
Source: Konopacki, S. and H. Akbari. “Measured Energy Savings and Demand Reduction from a Reflective Roof Membrane on a Large Retail Store in Austin.” Heat Island Group, Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, June 2001.

Cool Roofing & Energy Savings: First Field Study

Presented below are the highlights of the study findings.

- The average summertime roof surface temperature was 168°F for the black roof, and 126°F for the white roof, a 42°F difference.
- The average daily air conditioning savings were 11% for the white roof, which they calculated to be 7½ cents a square foot in energy costs at that time. In 2014 dollars, it would be about 9½ cents a square foot.





Cool Roofing & Energy Savings in Cold Climates

Allegation:

Although generally acknowledged that cool roofs result in net energy savings in hot/warm climates where air-conditioning loads are greater, some believe that cool roofs in cold climates result in a wintertime “heating energy penalty,” which causes net annual energy losses. Their reasoning follows that heating requirements are greater in cold climates; therefore, a dark, “non-cool” roof would be more effective from an energy consumption perspective.

Fact:

Cool roofs can result in net energy savings in pretty much any climate in the continental U.S. and in fact, even parts of Alaska, although not all of it.

The following slides will illustrate that the net energy savings predicted by many of the models is supported by field data and experience.

Cool Roofing & Energy Savings

Lawrence Berkeley did a study in which they modeled cities across the country to determine the potential impact of changing 80% of the roof surfaces over conditioned spaces to cool roofing materials with an aged solar reflectivity of 55%. They considered different types and ages of buildings, taking into account other variables in each location, including energy sources and costs.

They found cooling energy savings would result in all states, even in northern states like New Hampshire, Illinois, and Michigan.

Overall average savings for the entire U.S. were estimated to be five kilowatt-hours per square meter of conditioned roof area. Although they looked at all states, only a few examples are presented in the table to the right.

State	Cooling Energy Saving kWh/m² CRA
California	6.13
Nevada	6.86
Florida	5.72
New Hampshire	5.35
Minnesota	4.17
Illinois	4.22
United States Overall Average	5.02

Source: Levinson, R. and H. Akbari. “Potential Benefits of Cool Roofs on Commercial Buildings: Conserving Energy, Saving Money, and Reducing Emission of Greenhouse Gases and Air Pollutants.” *Energy Efficiency*, 3(1), 53-109, 2010.

Heating Penalties

So, do cool roofs result in a heating penalty in northern climates?

According to the Lawrence Berkeley study, they can, although the magnitude is generally small as shown in the last column in this chart. Look at how the heating energy penalty of Minnesota (0.137) compares to that of California (0.0292).

The important question is, what is the net impact over the whole year?

State	Cooling Energy Saving kWh/m² CRA	Heating Energy Penalty therm/m² CRA
California	6.13	0.0292
Nevada	6.86	0.0737
Florida	5.72	0.0115
New Hampshire	5.35	0.121
Minnesota	4.17	0.137
Illinois	4.22	0.0994
Unites States Overall Average	5.02	0.0645

Cooling Energy Savings vs. Heating Penalties

According to Lawrence Berkeley's modeling, with the exception of the most extreme conditions, such as areas in northern Alaska, the net effect is a positive overall annual energy savings in dollars per square meter of conditioned roof area.

The study concluded that year-round energy savings are achieved with cool roofs, even in the northern states.

State	Cooling Energy Saving kWh/m^2 CRA	Heating Energy Penalty therm/m^2 CRA	Energy Cost Saving (\$/m^2 CRA)
California	6.13	0.0292	0.699
Nevada	6.86	0.0737	0.570
Florida	5.72	0.0115	0.448
New Hampshire	5.35	0.121	0.482
Minnesota	4.17	0.137	0.136
Illinois	4.22	0.0994	0.217
United States Overall Average	5.02	0.0645	0.356

Cool Roofs in Cold Climates

Here’s a review of the reasons why cool roofs are effective in cold climates, a fact that may be counterintuitive to many.

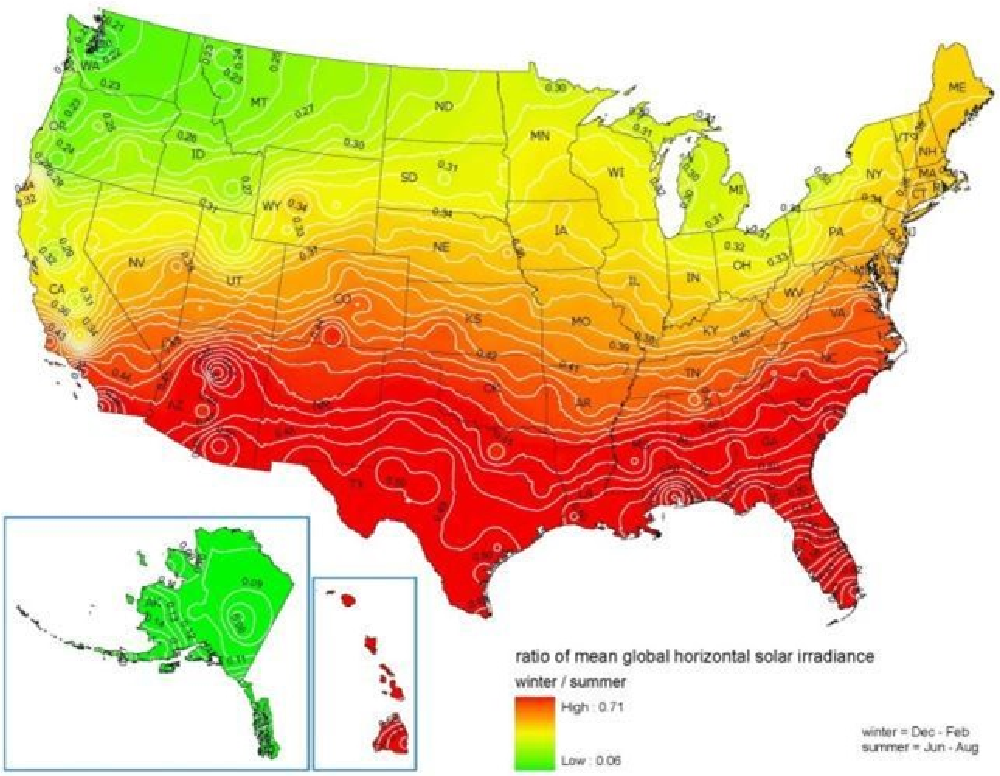
- In some cases, roofs are covered in snow for a long period of time, making the color of the roof membrane irrelevant.
- Winter days are shorter, with fewer potential hours of sunshine; therefore, the roof is exposed to much less of the sun’s energy.
- The sun is lower to the horizon during winter, resulting in less intensity and warmth.
- There is a higher incidence of cloudy days in the winter.

All of these factors combined reduce the amount of energy from the sun acting on the roofs, regardless of their color.

Solar Irradiance: Winter vs. Summer

Quantitatively, in the winter months, northern states typically experience 20% to 35% of the solar irradiance they are exposed to in the summer.

The result is that cool roofs provide significant benefits in the hot summer months, while they are only minimally affected in the winter months, with the net effect generally being positive over the course of the year.



Higher Insulation Levels & Cool Roofing

Allegation:
Building and energy codes are mandating the use of more insulation. Some would suggest that cool roofs do not provide any energy saving benefits in roofs with high levels of insulation.

Fact:
The University of Wisconsin studied the potential energy saving benefits of cool roofs on big box retail buildings using different insulation levels in two cities: Denver and Minneapolis. The results are shown in the table on the right.

Big box retail is important from an energy perspective because the roof makes up such a large proportion of the building envelope; therefore, it has a significant impact on the energy costs in these types of facilities. Although the magnitude of savings varies with insulation thickness, net energy savings can be achieved using cool roof assemblies even with higher insulation levels.

	Denver		Minneapolis	
Roof Insulation	R-4	R-24	R-4	R-24
Calculated Annual Net Energy Savings $/1,000 ft^2	47.74	16.09	27.33	10.04

Source: "White Roofs in Northern Climates: Simulated Influence of the Roof Reflectance on the Building Energy Balance in Two Northern Cities." ASHRAE Tech Paper, 2007.

Higher Insulation Levels & Cool Roofing

Oak Ridge National Laboratory (ORNL) approached it in a different manner. They selected the ASHRAE prescribed amount of insulation for new construction for a representative city from each ASHRAE climate zone, one through eight.

Using their Simplified Thermal Analysis of Roofs (STAR) energy calculator, they determined the heat flow through a cool roof with the noted amount of insulation at each location over a one-year period. Next, they ran the calculations to determine how much insulation would be required for a black roof to achieve the same thermal performance as a cool roof.

They found that to get equivalent energy performance between the white roof and the black roof in Florida, you would have to add R17 to the black roof—about 85% more insulation.

Even in Fairbanks, Alaska, with R35 insulation, an additional R3 of insulation is required for the black roof to achieve the same energy performance as the white roof.

Climate Zone	Representative City	Default R-Value for White Roof New Construction	Additional R-Value Required for Black Roof New Construction
1	Miami, FL	20	17
2	Austin, TX	25	16
3	Atlanta, GA	25	11
4	Baltimore, MD	30	10
5	Chicago, IL	30	6
6	Minneapolis, MN	30	5
7	Fargo, ND	35	5
8	Fairbanks, AK	35	3

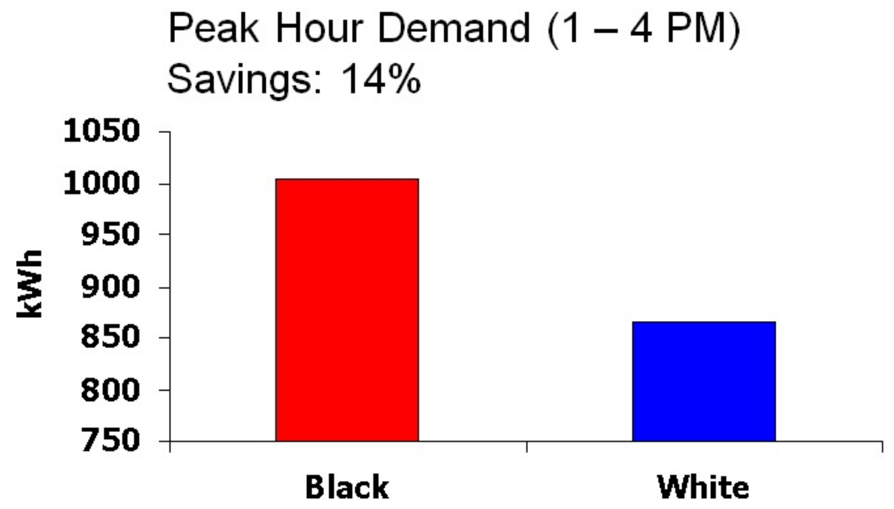
Source: Desjarlais, A., et al. “Trading Off Cool Roofs for Insulation.” ORNL, Cool Roof Rating Council, AGM, 2012.

Peak Demand Hours

It is important to note that cool roof benefits are greatest during peak demand hours, typically between 1:00 p.m. and 4:00 p.m.

Referring back to the Lawrence Berkeley study on the Target store in Austin, the net energy savings was approximately 11% annually, while the peak energy savings between 1:00 p.m. and 4:00 p.m. was about 14%.

Peak energy demand is critical. During peak hours, people are at work, stores are open, plants are running, buildings are operating, etc.



Source: Konopacki, S. and H. Akbari. “Measured Energy Savings and Demand Reduction from a Reflective Roof Membrane on a Large Retail Store in Austin.” Heat Island Group, Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, June 2001.

Peak Demand Hours

Peak energy demand drives power plant construction.

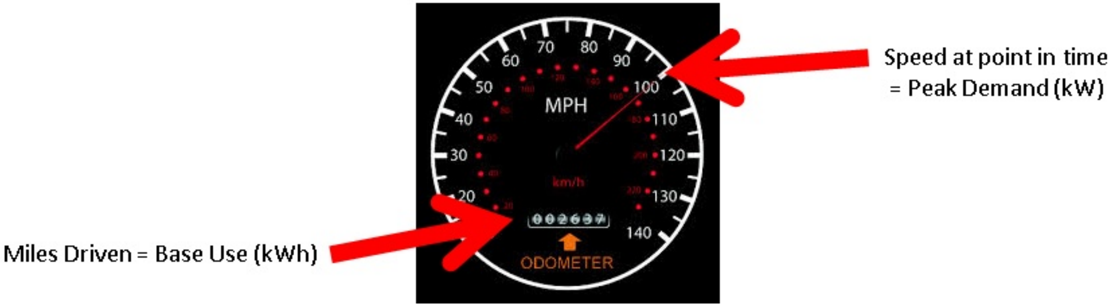
During peak hours there can be power shortages, while during non-peak hours, generating plants are under-utilized. Unfortunately, electricity cannot be easily stored. You may recall the brown-outs California experienced a number of years ago. Whole sections of the state were without power midday because the peak demand exceeded capacity.

Reducing peak demand was one of the drivers of the state’s energy code, California’s Title 24.

Peak Demand Charges

Utilities need to cover their fixed costs, including the times when their assets are under-utilized during non-peak demand hours. They do so through “peak demand charges.” A peak demand charge is based on the highest amount of electricity consumed for a defined interval, such as 15 or 30 minutes, during the billing period. Measured in kilowatts (kW), it is independent of the overall base use or consumption that is measured in kilowatt-hours (kWh).

One way to look at it is by comparing it to the instrumentation in a car. The odometer reflects the total mileage, much like the total consumption of electricity is tracked by an electric meter. Much like the car speedometer reflects the maximum speed at a given point in time, peak demand is a measurement of the maximum consumption within a billing period.



Hoff, James L., Keith Gere, and Robert Carnick. “Reducing Peak Energy Demand: A Hidden Benefit of Cool Roofs.” TEGNOS Research, Inc., n.d. Web.

Peak Demand Charges: Warehouse Example

This chart shows an example of electricity charges for a warehouse in Canton, Massachusetts.

In July 2014, the warehouse consumed a total of 10,080 kWh of electricity and was billed $2,788.40.

At a base rate of $0.073/ kWh, their base charge for the billing period was $735.18.

The demand charges, totaling $2,053.22, accounted for 74% of the total, and almost quadrupled their base cost of electricity.

Warehouse, Canton, Massachusetts, July 2014	
Total kWh Used	10,080
Cost	$0.073/kWh
Total kWh (Base Charge)	$735.18
Demand Charge	$2,053.22
Total Charges	$2,788.40
Demand Charge %	74% of Total Bill
Net Cost per kWh	$0.277 kWh

Peak Demand Charges: Comparison

Let's compare two customers.

Customer A has a peak demand of 50 kW that is consumed over 50 hours; customer B has a peak demand of 5 kW that is consumed over 500 hours. Although both customers use 2,500 kWh of energy, customer A's peak demand charge is more than three times that of customer B.

It is important to note that peak demand charges are not considered in most common energy savings calculators. As a result, the calculations yield results that are more conservative with regard to the net energy savings resulting from the use of cool roofs.

	Customer A	Customer B
Peak Demand	50 kW	5 kW
Usage	50 Hrs.	500 Hrs.
Total Used	2,500 kWh	2,500 kWh
Peak Demand Charge	$1,775.00	$515.00

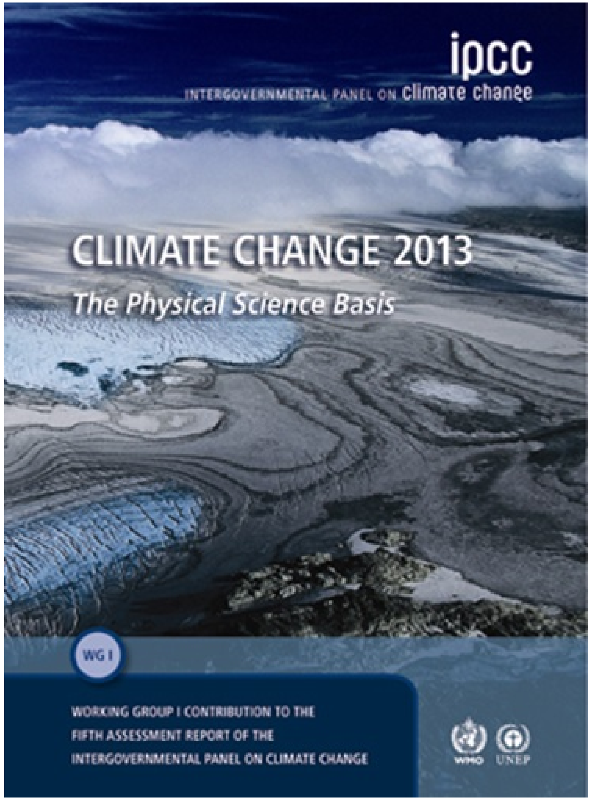
Source: Grohman, M. "Clear As Glass: Reflective Roof Systems Offer Obvious Energy Savings." *Professional Roofing.* NRCA, November 2014.

Climate Change: Increasing Benefits of Cool Roofing

The magnitude of cool roofing-related benefits is likely to increase over time.

The Intergovernmental Panel on Climate Change anticipates that by the end of the 21st century, in North America the hottest temperature event will increase from one in every 20-year period to one in every two-year period. That means that the hottest temperatures occurring once per generation will become commonplace.

During that same timeframe, they anticipate the maximum daily temperature will rise two to five degrees Fahrenheit above current levels.

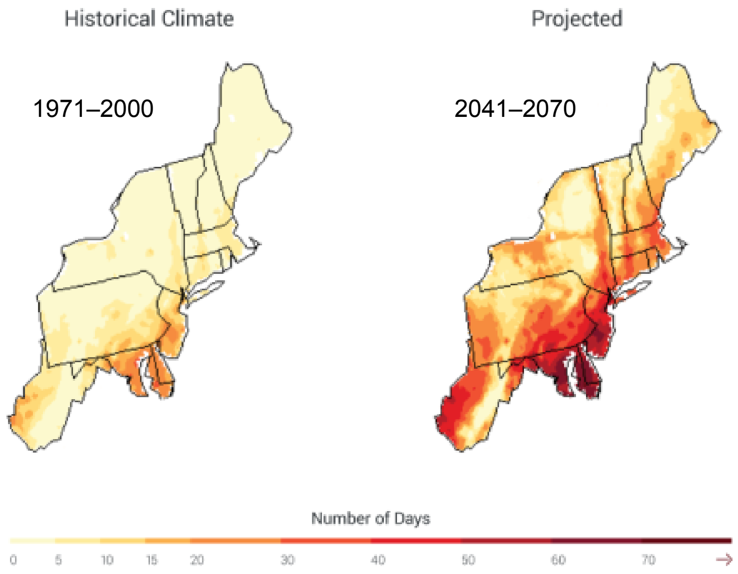


Climate Change: Increasing Benefits of Cool Roofing

The National Climate Assessment Report highlights a number of anticipated consequences of global warming, such as the number of days above 90°F.

The map on the left represents the number of days above 90°F annually in the Northeast between 1971 and 2000. As can be seen, some areas of the southern portion of the New England states have averaged roughly 20 days per year from 1971 to 2000.

The map on the right projects that if we continue to use energy and to generate greenhouse gases at the current rates, between 2041 and 2070 many areas will experience over 70 days above 90°F a year, and in some locations, up to 90 days. That translates to nearly every day of the summer season reaching temperatures above 90°F.



Projected increase in the number of days per year with a maximum temperature greater than 90°F averaged between 2041 and 2070, compared to 1971-2000, assuming continued increases in global emissions and substantial reductions in future emissions. (Figure source: NOAA NCDC / CICS-NC)

Calculations, Models, & Simulations

Most of the information presented in this course so far is based on calculations, models, and simulations. These are useful tools, but they can have shortcomings as results depend on the quality of the tool and data input.

There used to be two different cool roof calculators: one from the DOE and one from the EPA. These two calculators were combined into one known as the Roof Savings Calculator (RSC). A number of articles and bulletins have been written based primarily on calculations carried out with the RSC, calling into question the benefits of cool roofs, particularly in colder climates.

It is important to note that although it is available on-line, the calculator is still a work in progress and, as such, there is an advisory posted which states: “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.” Some authors neglect to mention this caveat when presenting data based on RSC calculations.

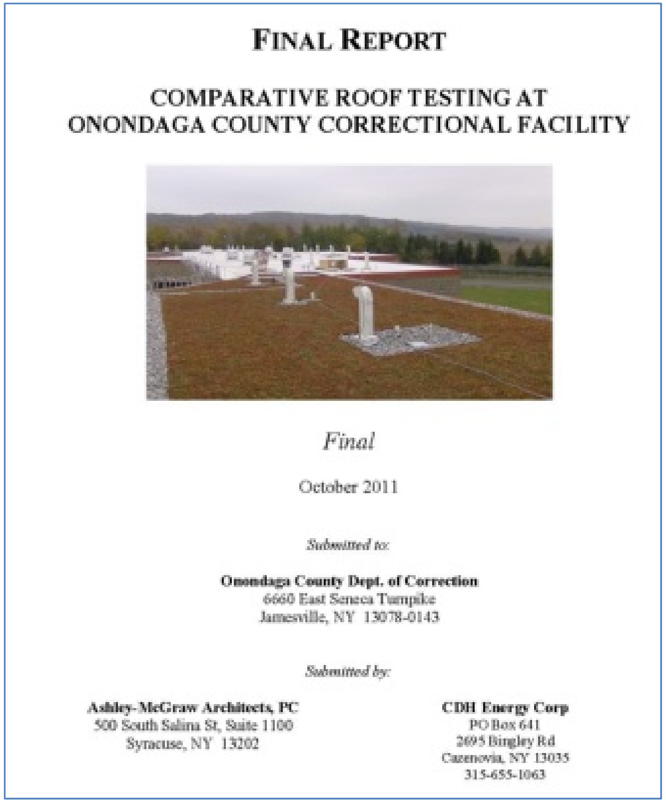
Another potential issue is the quality of the data used. These models are generally based on numerous assumptions, which may or may not be realistic. An example of this is presented in subsequent slides.

All of these points make it very difficult to compare studies and assess their respective results and conclusions.

The Importance of Looking Into the Details

The “Final Report: Comparative Roof Testing at Onondaga County Correctional Facility,” is based on a study conducted in upstate New York in which four correctional residential buildings, essentially identical, were re-roofed and monitored from fall 2009 to spring 2011. The fundamental goal was to compare the energy performance of a white TPO roof to a black EPDM roof with the same amount of insulation.

The report concluded that dark roofs are more energy efficient in New York State than white roofs. However, when you examine the data more closely, the conclusion is misleading. For example, the report highlights “typical summer days” and cites temperatures around 71°F for May 12, 16, and 29 of 2010. However, the weather records for Jamesville, New York for summer 2010 indicate there were numerous days in July above 90°F. Representing 71°F days in May as “typical summer days” is misleading.



FINAL REPORT

COMPARATIVE ROOF TESTING AT
ONONDAGA COUNTY CORRECTIONAL FACILITY

Final

October 2011

Submitted to:

Onondaga County Dept. of Correction
6660 East Seneca Turnpike
Jamesville, NY 13078-0143

Submitted by:

Ashley-McGraw Architects, PC
500 South Salina St, Suite 1100
Syracuse, NY 13202

CDH Energy Corp
PO Box 641
2695 Bingley Rd
Cazenovia, NY 13035
315-655-1063

The Importance of Looking Into the Details

Furthermore, the buildings in the study are not air conditioned. That critical fact appears in a footnote: “although the correctional facility does not have cooling, the authors conducted their assessment assuming the facility did have cooling.” That is a very significant assumption in a study on the performance of cool roof materials.

The report stated that the overall savings from the TPO roof were slightly negative, with the cooling and heating savings essentially cancelling out. Their evaluation was based on costs of a dollar per therm for heating, and $0.12/kWh for cooling.

However, according to the U.S. Energy Information Administration database, although the heating cost is correct, the actual cost for electricity in New York State that summer was $0.16/kWh; the $0.12/kWh was the national average.

	Heating	Cooling
	Measured	**Calculated**
Costs used for calculation	$1.00/Therm	$0.12/kWh
U.S. Energy Information Administration, NY State	$1.00/Therm	**$0.16/kWh**

The actual cost of electricity was 30% higher (16 cents versus 12 cents) than the calculated cost.

The Importance of Looking Into the Details

Let's look at the effect of using the actual cooling energy costs.

The columns showing the data for $0.12/kWh were taken from the report and the numbers are rounded off for simplicity. The report data shows that, compared to the black roof, the white roof costs $2 per thousand square feet more in net energy costs throughout the year.

In the columns on the right, the same analysis is made using the correct electricity cost of $0.16/kWh.

The net energy savings for the cool roof is actually $4/1000 ft^2, confirming that, contrary to the report's conclusion, even in northern New York, cool roofs provide net annual energy savings compared to black roofs.

	@$0.12/kWh		**@$0.16/kWh**	
	EPDM	TPO	EPDM	TPO
Gas usage, Therms/1000Ft^2	61.1	79.5	27.33	10.04
Annual Heating Cost/1000Ft^2	$61	$80	$61	$80
Heating Savings/1000Ft^2		($18)		($18)
Reduced Cooling Power (kWh/yr per 1000Ft^2)		137.3		
Cooling Savings		$16		$22
Net savings/1000Ft^2		**($2)**		**$4**

Cool Roofs in Practice

Cool Roofs in Practice: Target Retail Stores

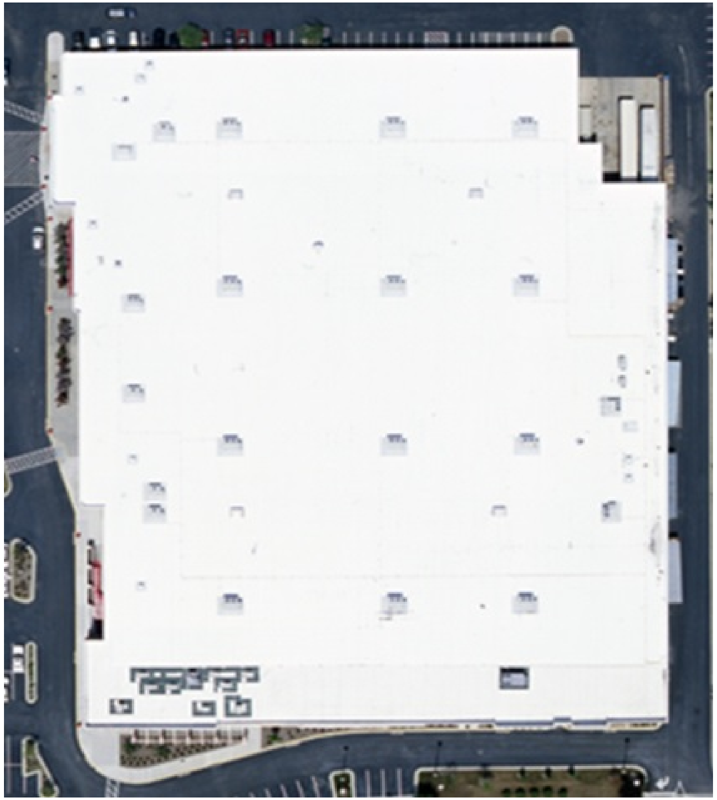
Target stores provide an interesting case study as they have approximately 2,000 stores located across the U.S. in all climate zones. The roof of a typical Target store comprises more than three-quarters of the entire building envelope. With energy accounting for more than half of their operational costs, the energy performance of the roof is critical.

Cool Roofs in Practice: Target Retail Stores

About 20 years ago, Target began shifting from black EPDM roofs to white thermoplastic PVC roofs. And about 10 years ago, they made this switch across their entire real estate portfolio.

The critical elements with regard to their roofs include:

- performance (the roof has to provide long-term, problem-free service)
- energy efficiency (due to the large footprint of a typical Target store, the roof must be energy efficient), and
- consistency (having the same roofing materials for all their buildings facilitates construction and maintenance).



Cool Roofs in Practice: Target Retail Stores

Listed below are some excerpts from an article published in the fall 2014 issue of *Architectural Roofing and Waterproofing* that was co-authored by Target.

- Target has not experienced a net “heating penalty.”
- Although magnitude varies from significant to modest with location, Target has experienced net positive energy impact from cool roofs, even in locations with lengthy heating seasons.
- Target has not experienced any measurable reduction of energy consumption during winter seasons on the few “non-cool” dark roofs it has left in northern climates.

In conclusion, decades of experience in Target stores demonstrate that cool roofs do provide net energy savings in northern climates.

Undesirable Glare

Allegation:
Highly reflective cool roof materials can generate undesirable glare in adjacent structures.

Fact:
By their very nature, cool roof materials do reflect the sun's rays; however, in some instances, the reflected light can be beneficial.

One watt of daylight can replace up to two watts of fluorescent lighting. Each watt of reflected light that comes into the building can potentially save up to a watt of artificial lighting and the associated energy demand and heat load in the building.

There are instances where reflected light or glare may be problematic. In locations where there is a sensitivity to glare, there are cool roof colors (cool greys, cool tans, etc.) that will result in less glare, although they are not quite as energy efficient as highly-reflective white materials.

Reflectivity of Aged Cool Roofing Materials

Allegation:

Cool roofs soil over time, negating their benefits.

Fact:

Like all other outdoor surfaces, cool roofs will get dirty over time. The degree of soiling depends on a number of variables, including:

- location and geography
- local climate
- surroundings (urban, agricultural, industrial)
- amount and type of discharge from the building, and
- roof slope.

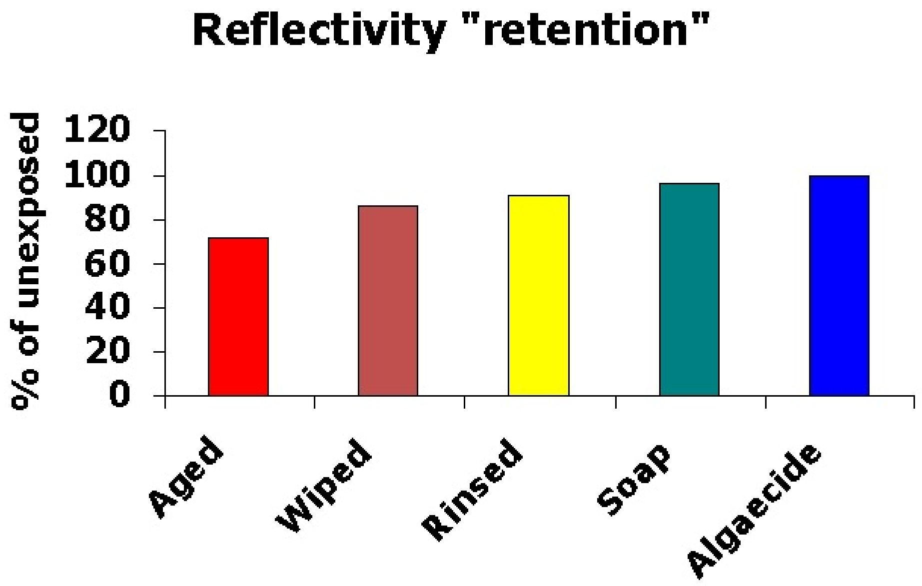
For example, in the Midwest, many power plants burn coal, which results in a lot of particulate matter in the air. A building in an industrial park is likely to get more dirty than one in a residential area. Tilling of soil for agriculture can have an impact on the degree of soiling of the cool roof. The lower the slope, the more likely a roof is to retain dirt.

Reflectivity of Aged Cool Roofing Materials

Lawrence Berkeley National Laboratory and the National Research Council of Canada studied soiling of thermoplastic membranes.

They collected samples from roofs of various ages across the U.S. and Canada and found that, on average, the aged reflectivity was about 70% of that of new material.

By simply wiping the samples, reflectivity increased on average to just over 80% of the original reflectivity. Rinsing the samples in water brought them to about 90%. Using soap, average reflectivity increased to roughly 95% and if they used an algaecide, they could return the samples to close to their original reflectivity level.



Source: Akbari, H., Berhe, A.A., Levinson, R., Graveline, S.P., Foley, K., Delgado, A.H., Paroli, R. M. “Aging and Weathering of Cool Roofing Membranes.” Cutting Through the Glare Symposium, Atlanta, GA, May, 2005

Reflectivity of Aged Cool Roofing Materials

Although possible, cleaning of low slope roofs is rarely done.

How reflective are roofs that do get dirty?

The Cool Roof Rating Council (CRRC) was established to develop testing and aging protocols for determining the solar properties of roofing materials, and to maintain a database of the results for California's Title 24 energy code.

Material reflectivity and emissivity values are measured after three years of weathering at three locations, representing three different climate zones: hot and humid in Florida, cold in Illinois, hot and dry in Arizona.

Research has shown that the degree of rooftop soiling tends to level off at about three years, which was the reason for the CRRC's decision to base the program on three-year-aged data.

Reflectivity of Aged Cool Roofing Materials

This data is compiled in the CRRC's Rated Products Directory, which can be found at www.coolroofs.org (Accessed January 2017).

Currently, there are roughly 448 products with an initial reflectivity greater than 70% and initial emissivity greater than 75%, which was the requirement for Title 24 at the time the roofs were installed.

- The average initial reflectivity of all these 448 products was 82%.
- The average aged reflectivity for all these products was 69%.
- More than 90% of these materials had an aged reflectivity that was higher than 60%.

Lawrence Berkeley and others typically base all their modeling and analysis on an aged reflectivity of 55%. Based on the CRRC database, the Lawrence Berkeley data is conservative with 90% of these cool roof materials being over 60% aged reflectivity, and the average being over 65%. So even when they get soiled, cool roofs still provide significant cooling and net energy savings.

Typically, aged reflectivity values exceed those used in most studies, models, and analysis. Even taking potential soiling into account, cool roof materials provide net energy savings annually.

Moisture Accumulation

Allegation:

In colder climates, cool roofs may be cooler in winter months and may be more prone to condensation than dark roofs. Cool roofs may not heat up sufficiently in the summer months to dry out any condensate that may have formed in the winter, which could lead to premature deterioration of the cool roof system.

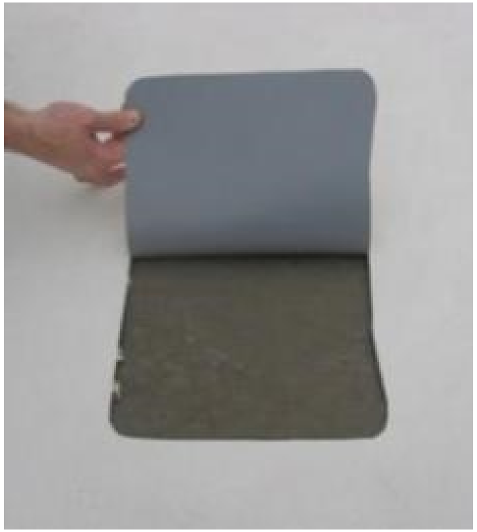
Fact:

The Single Ply Roofing Industry (SPRI) undertook a field survey to determine if there was an issue with condensation in cool roofs in cool climates. The test roof systems were cut and examined for moisture accumulation. Ten roofs were surveyed (nine TPO, one PVC) in various states (climate zone five), including Illinois, Michigan, New Hampshire, and Pennsylvania. The study was purposely designed to provide the worst-case scenario for finding condensation within the roofs surveyed. Test cuts were done during the winter, before 10:30 a.m. so the roof was not exposed to much sunlight. All the roofs had a steel deck, a single layer of insulation, a mechanically attached membrane, and no vapor retarder. The roofs were in place at least five years and all the buildings were climate controlled, i.e., they had to be heated in the winter.

Source: Ennis, M., M. Keher. “The Effects of Roof Membrane Color on Moisture Accumulation in Low-slope Commercial Roof Systems.” 2011 International Roofing Symposium, Washington, DC

Moisture Accumulation

SPRI observed some dampness or surface moisture on the back side of the membrane in three of the TPO roofs. In every case, they found the insulation cores and decks were dry, and there were no detrimental effects to the roofing systems.



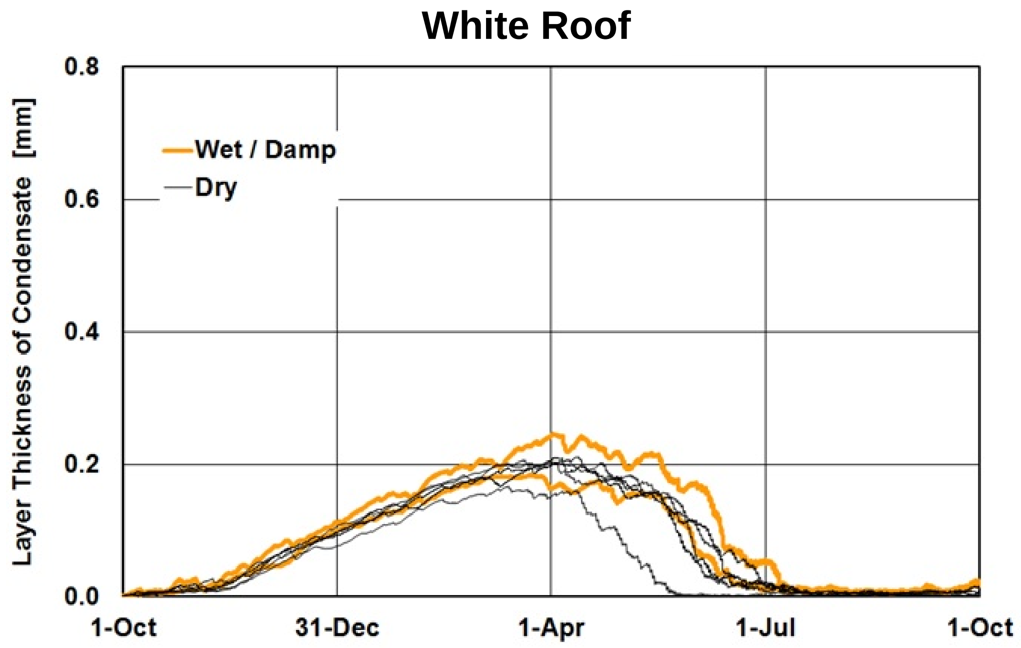
Images courtesy of Single Ply Roofing Industry

Moisture Accumulation

WUFI® is a suite of software products that allows realistic calculation of heat and moisture transport in walls and other multi-layer building components.

SPRI ran two WUFI® analyses for each of the test roofs: one for a black membrane, one for a white membrane. They found that modest amounts of moisture could be generated under both colors of membranes, although more moisture appeared under the white membrane than under the black.

However, in all cases, the calculations showed that the moisture dried up completely in the summer months, confirming that the self-drying concept is equally applicable for cool roofs as for dark roofs.



Layer thickness about 0.2 mm (8 mil) maximum (vs. 0.08 mm (3 mil) for black)
All roofs accumulate water during the winter and dry out completely in summer.

Image courtesy of Single Ply Roofing Industry

Moisture Accumulation: Concept of Self-Drying Roofs

The concept of the self-drying roof has been around for many decades.

The premise is simple: without a vapor retarder, moisture may condense in a roofing system during the winter months. The condensation can be caused by moist, warm air inside the building that migrates upwards to the coldest surface. Any condensate that may form during wintertime dries out during the summer months. The net effect is that there is no accumulation of moisture within the roof assembly. This method of roof design has been in place in the U.S. for a very long time and is the reason why vapor retarders are not used often.

Although the SPRI work was a useful study, many people either misinterpret or misrepresent the results. They often wrongly claim that three out of the ten cool roofs surveyed were failing, which is not true. In fact, the study states that no damage was observed in those types of roofs, and the WUFI analysis showed all the roofs fully dry out in the summer months.

Moisture Accumulation: Target Store Roof System Design

Target stores are the same type of buildings that SPRI used in their study.

Typically, the Target store roof system is composed of a single layer of iso insulation over a steel deck with a mechanically attached, highly-reflective, thermoplastic PVC membrane.

Recently, Target has started to include high-density iso cover boards for hail resistance and other purposes.

Moisture Accumulation: Target Store Field Survey

Twenty-six Target stores were surveyed in the states of Connecticut, Illinois, Massachusetts, Michigan, Minnesota, New York, Washington, and Wisconsin, covering ASHRAE climate zones four, five, and six.

All the roofs were at least 10 years old and were mechanically attached PVC.

Eleven of the stores had a single layer of iso (between two and three inches thick) installed on the steel deck.

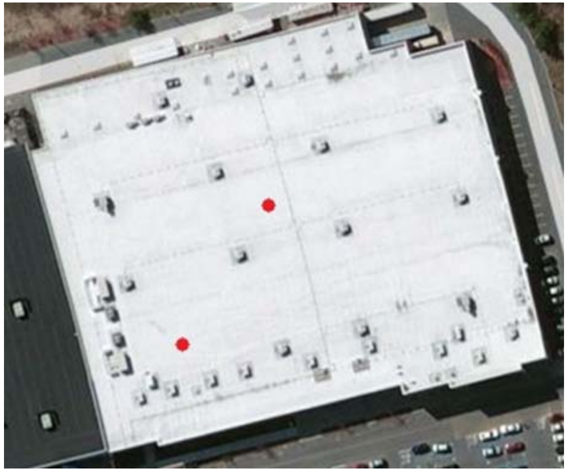
Eleven of the stores had two layers, typically iso and a cover board—in the odd case, two layers of iso. None had a vapor retarder.

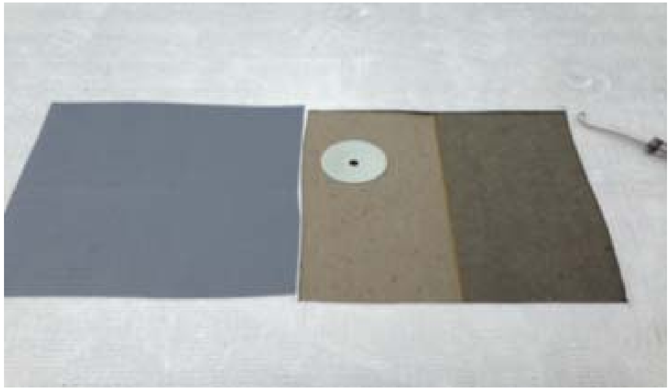
Four stores had re-covers: an existing roof (either EPDM or PVC), a cover board, and a new membrane.

Moisture Accumulation: Target Store Field Survey

The technicians chose two spots randomly, far apart on each roof for cut-tests. They cut them open, and checked for moisture, staining, and corrosion at every level in the assembly. All cuts were done over an insulation board joint, as this would present the worst-case scenario.

The same procedure was performed on all 26 roofs, and on all 26 roofs, in all 52 cuts, all layers were dry. There was no evidence of moisture, condensation, or damage of any kind.





Target Store Roof Management Program

Target has a very proactive roof management program. They re-skin their roofs before the membrane fails. They recognize the high cost of roof insulation. Replacing the membrane before it fails allows them to maintain the existing insulation, as opposed to waiting for the roof to fail, having the insulation get wet, and needing to replace it as well.

On occasion when they re-skin the roof during the winter, they may see a bit of frost on the back of the membrane or on the surface of the insulation, which is not surprising. The insulation and the deck are always dry, and unless there was some localized leakage, they leave all the insulation in place, and install the new membrane, thereby getting the full benefit of the existing insulation. The process has been done on hundreds of roofs in all climates, and they managed to keep the insulation on all those roofs.

Therefore, the survey simply confirmed what they already knew. The membrane that is removed is recycled back into new membrane, helping them towards their goal of zero construction waste.

Results of Target Store Field Survey

The results of the Target store field survey, as well as their experience with cool roofs, has been documented and published in the:

- Fall 2014 issue of *Architectural Roofing and Waterproofing*, and
- October 2014 issue of *Roofing Contractor*.

Fenner, Michael, Michael Dipietro, and Stanley Graveline. "Case Study: Cool Roofs in Use in Northern Climates." *Architectural Roofing and Waterproofing*, Fall 2014, pp.16-21, www.vinylroofs.org/documents/CoolRoofsinUseinNorthernClimates.pdf. Accessed January 2017.

Fenner, Michael, Michael Dipietro, and Stanley Graveline. "Study Targets Cool. Assessing the Performance of Cool Roofs in Northern Climates." *Roofing Contractor,* October 2014, pp.42-46, http://www.vinylroofs.org/documents/StudyTargetsCoolRoofs-AssessingthePerformanceofCoolRoofsinNorthernClimates.pdf. Accessed January 2017.

Moisture Accumulation

Allegation:

In colder climates, cool roofs may be cooler in winter months and may be more prone to condensation than dark roofs.

Fact:

The Department of Energy put out a manual on guidelines for selecting cool roofs, where they addressed this allegation head-on. In their manual they note that while this issue of condensation in roofs has been observed in both cool and dark roofs in cold climates, the authors are not aware of any data that clearly demonstrates a higher occurrence in cool roofs. The Target store field study and their experience over decades certainly supports that statement.

All roofs need to be designed properly, and if there is a need for a vapor retarder, roof color is not a determining factor.

★ Please remember the **exam password STUDY**. You will be required to enter it in order to proceed with the online examination.

Source: Urban, B. and K. Roth. "Guidelines for Selecting Cool Roofs." U.S. Department of Energy, Building Technologies Program, July 2010, V. 1.2.

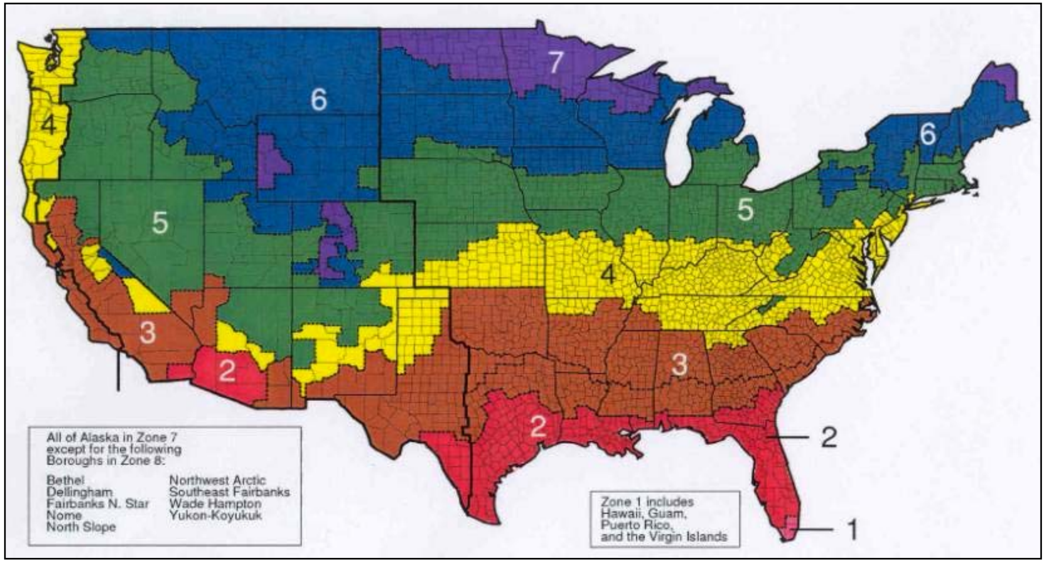
Proven Performance

Allegation:

Cool roofs are “new” and “unproven.”

Fact:

Although some cool roof materials may have more modest track records, some thermoplastic PVC membranes have a track record of proven performance second to none, having been used successfully for more than 40 years in all climates across North America, and more than 50 years in Europe.



Based on industry statistics, it is estimated that between 2002 and 2013, more than 5 billion square feet of thermoplastic roofs, of which almost all are cool roofs, were sold in climate zones five and above. Clearly cool roofs are performing in northern climates.

Proven Performance

Some companies have done nothing but “cool roofs” going right back to their origins over 50 years ago in Europe.

This is a building in Personico, Switzerland. It was installed in 1968 and is still in service today in 2017.

Proven Performance

Light colored PVC roofs have been used for more than 40 years in North America. The four oldest manufacturers of thermoplastic membranes in North America are all located in the Northeast, Midwest, and Canada.

Like most businesses, their first sales, and now oldest references, tended to be close to their plants, all in northern climates. For example, the PVC membrane roof on the First Methodist Church, Laconia, New Hampshire seen in this photo was installed in 1976 and is still in service. Individually, some of these companies have sold more than 1.5 billion square feet of cool roof membranes in North America, roughly half of which is estimated to have been installed in northern climates.

Conclusions

Conclusions

Cool roofs have demonstrated in service that they can provide:

- cooling energy savings
- peak demand electricity reduction, and
- net energy savings in all but the most extreme climates (e.g., parts of Alaska).

Conclusions

Cool roofs can be an important contributor to a reduction in the urban heat island effect and its consequences such as smog and greenhouse gas (GHG) emissions.

Some cool roof membrane technologies such as thermoplastic PVC have a track record of many decades of proven performance across North America.

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References & Resources

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Conclusion

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