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Cool Roofs for a Hot Planet

Today's cool roofing systems are a significant platform for urban building sustainability

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Learning Objectives

After reading this article, you should be able to:

1. Discuss the science and background of cool roofing systems.
2. Describe the basics of thermoplastic single-ply roofing.
3. Identify myths and realities of PVC cool roofing.
4. Describe the role cool vinyl roofing plays in sustainable building design.
5. Identify key criteria for roof selection.

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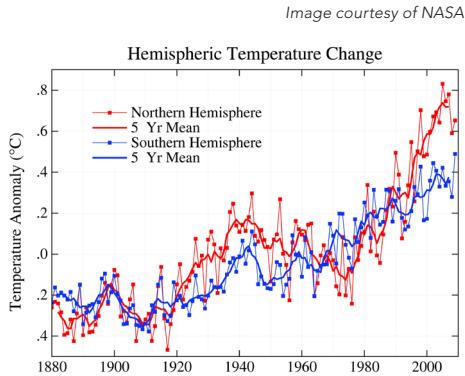
Many scientists agree that the planet is warming quicker than the natural forces of nature have ever brought about, and those scientists maintain that such quickening is caused in large part by human activity.

As the planet warms, the world's population continues to move into urban areas that are heating up at twice the rate of global warming due to human activity, lack of vegetation, and the use of dark roofing and paving materials.

This article discusses the role of cool, reflective roofing, and specifically the role of PVC roofing as a way to decrease energy use and thereby decrease emissions. PVC single-ply roofing deflects heat from buildings, decreases energy use, mitigates urban heat islands, and serves as a durable platform for photovoltaic systems and vegetative roofs.

WHAT IS A HOT PLANET?

We have always lived in a greenhouse of sorts. The atmosphere traps the heat of the sun, which allows living beings to live and thrive. Many scientists maintain the expansion of that greenhouse effect, via gases that block solar heat from escaping back out of the atmosphere,



According to NASA, January 2000 to December 2009 was the warmest decade on record.

causes the planet to heat up at a rate too quickly for nature to adapt.ⁱ The U.S. Dept. of Defense considers climate change "an urgent and growing threat to our national security".ⁱⁱ

According to NASA, the world's leading climate research agency: "Multiple studies published in peer-reviewed scientific journals show that 97 percent or more of actively publishing climate scientists agree: Climate-warming trends over the past century are very likely due to human activities. In addition, most of the leading scientific organizations worldwide have issued public statements endorsing this position."

Those issuing statements regarding climate include: the American Chemical Society, the American Medical Association, U.S. National

Academy of Sciences, American Geophysical Union, American Meteorological Society, and the Intergovernmental Panel on Climate Change.ⁱⁱⁱ

Additionally, cities are growing at an incredible rate worldwide—and they are heating up at a faster rate than global averages. They are particularly vulnerable to heat-related issues like air quality and health issues from heat. While most people don't think about roofs, they can be 25 percent to 30 percent of total city area, making them a significant platform for urban sustainability that most people never have to interact with or notice. But roofs can be a part of the solution of hot cities. Roofs tend to be replaced more frequently than a building is retrofitted, so the rate of change (and rate of results) can be relatively quick. In short, smart roof usage is a climate strategy because it is immediately effective across a broad spectrum of benefits, and can be rolled out relatively quickly with good policy and good business decisions.

WHAT ARE COOL ROOFS?

Among the solutions to decrease energy use and thus decrease emissions from burning fossil fuels are cool roofing systems. Cool roofs use a highly reflective surface to direct a significant portion of solar heat from the

Photo courtesy of Duro-Last, Inc.



Cool roofs deflect solar energy away from a building and back to the atmosphere and beyond.

CURRENT COOL ROOF REFLECTANCE STANDARDS		
Reference Standard	Minimum Roof Reflectance	
	Initial	Aged
International Energy Conservation Code (2012)	0.70	0.55
ASHRAE 90.1 Energy Standard for Buildings (2011)	0.70	0.55
Energy Star for Roofs (U.S. EPA, 2012)	0.65	0.50
California Title 23 Energy Standard (2012)	N/A	0.63

sun away from the building. Unlike a dark or non-reflective roof surface that absorbs and transfers solar heat into the building and the surrounding neighborhood, a light-colored, reflective roof surface reflects and drives solar heat away from the building and into the atmosphere or beyond. Reflecting the sun's energy to keep cool is an ancient strategy that has been made modern with science and innovation. Cool roofs have been widely available in the U.S. marketplace for more than 25 years.

Cool roofs can be achieved using a wide variety of roofing technologies, including single-ply membranes, cool-surfaced modified asphalt systems, and metal roofing panels. A wide variety of roof coatings may be applied to many different roofing surfaces. For any of these roofing products to be "cool" by today's standards, the minimum percentage of solar heat reflected away from the building typically falls within a range of 0.50 (50 percent) to 0.70 (70 percent), depending on the particular standard being applied and the aging of the sample tested. The table to the left shows the most-recognized building codes and standards.^{iv}

BENEFITS OF COOL ROOFS

The cheapest roof is rarely the least expensive. While the upfront cost of the cheapest roof possible may appeal to an owner, the long-term benefits that will be sacrificed makes it a very bad bargain. While budget may seem like the overriding concern, the primary goal should be to design and construct a watertight roofing system as well as a superior building that will not only create a healthier and more comfortable environment for occupants, but will save the owner or operator money and trouble in the long run. In many cases, educating the owner is necessary so that the best decision for long-term benefits can be made.

There are compelling "talking points" that explain the real costs and benefits of a cool roof:

- **Insulation is from 25 to 50 percent more effective.** When insulation gets hot, it is less effective at doing what it is supposed to do—slow heat movement through the surface. The science shows that extremely high temperatures reduce the effective R-value of the most widely used types of insulation (Leonard & Leonard, 2005).
- **Improved HVAC efficiency.** Inlet air temperature can be 5 degrees to 15 degrees cooler 30 inches above the roof surface. Most HVAC units are designed with efficiency ratings evaluated at 95 degrees (York International, 2005).
- **Reduced heat flux.** Studies from Princeton University show with modeling and field tests that reflectivity noticeably reduces heat flux on roofs with as much as R-48 insulation. The authors conclude that cool roofs make sense because they save in the summer and don't really affect winter heating, especially in roofs with high levels of insulation.^v
- **Ambient interior temperatures can be 15 to 20 degrees cooler than outside with a cool roof.** According to a report by the Lawrence Berkeley National Laboratory and other researchers: "In many commercial buildings, thermal conditions are not

Photo courtesy of Duro-Last, Inc.



Rooftop HVAC equipment has been shown to work more efficiently in combination with a cool roof.

controlled well due to insufficient cooling or heating capacity, high internal or external loads, large thermal zones, improper control-system design or operation, or other factors.” The results of the study on worker productivity show that performance increases with temperature up to 70 to 71 degrees Fahrenheit, and decreases with temperature above 73 to 74 degrees Fahrenheit. The highest productivity is a temperature of around 71 to 72 degrees Fahrenheit. For example, at the temperature of 86 degrees Fahrenheit the performance is only 91.1 percent of the maximum, with the reduction in performance of 8.9 percent. In short, cool roofs can contribute to lowering the interior temperature and maintaining comfort levels for the occupants.

Reducing Peak Demand

Analysis of energy bills shows that peak demand charges accounts for a significant portion of monthly electric bills across the United States and that cool roofs provide an equally significant opportunity to reduce these charges when installed on air-conditioned buildings.

A sharp peak in electrical demand can be observed in buildings during the busiest hours of the day. Although a share of this peak may be attributed to equipment use in the building, a significant portion is caused by increased demand for air-conditioning in the heat of

the afternoon. This peak in demand requires additional power plant capacity, leads to a greater chance of brownouts and blackouts, and may result in increased air pollution.

But most importantly for your client, the building owner, peak demand may result in monthly charges many times higher than the base electrical rates. One of the best approaches to shrink peak demand is to reduce the heat load on a building, especially the solar load that drives the need for air-conditioning. Few heat-reduction strategies can match the energy-saving potential of modern cool roofing technology.

Cool Roofs and Urban Heat Islands

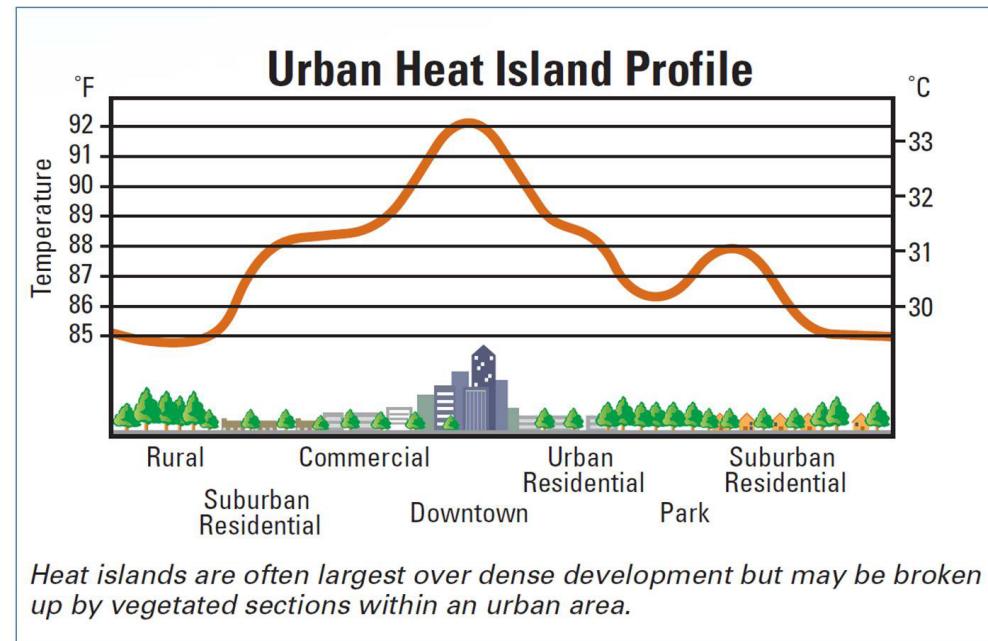
Heat islands are those urban areas where the temperatures will be hotter than the surrounding areas. Lawrence Berkeley National Laboratory (LBNL) has been the main research agency and proponent of heat island mitigation activities.^{vii}

As the chart below shows, on average the difference in afternoon temperatures between rural and urban land is 7 degrees Fahrenheit. In some areas, the difference is as much as 10 degrees Fahrenheit. This difference can increase during extended heat waves.

Three key factors make up the overwhelming majority of the 7-degree heat island difference:

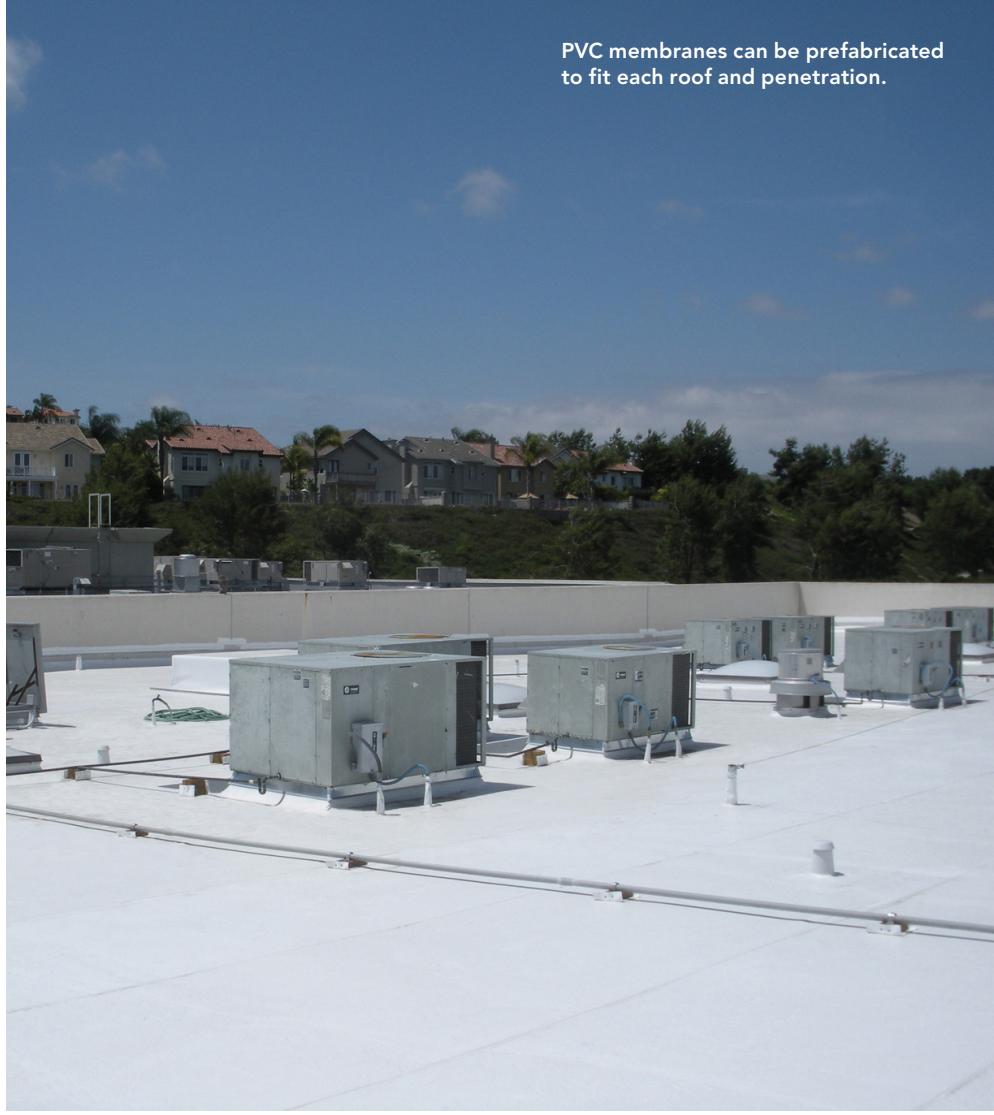
- 1) Fifty-six percent of the effect is due to less vegetation in the urban land compared to rural land (about 4 degrees).
- 2) Dark paving causes 6 percent of the difference (less than $\frac{1}{2}$ degree).
- 3) Thirty-eight percent is directly attributed to dark roofing (almost 3 degrees).^{viii}

Image courtesy of the Environmental Protection Agency



This chart shows that on average the difference between rural and urban areas is 7 degrees Fahrenheit, with some areas as much as 10 degrees hotter. This difference can increase during extended heat waves.^{vii}

Photo courtesy of Duro-Last, Inc.



Let's consider the possible solutions to heat islands. Adding vegetation will certainly help. However, it is a long-term improvement, requiring 10, 20, even 50 years to reap full benefits of, for instance, mature leafy trees. Such a remedy is constantly in a catch-up mode because construction and expansion continually removes vegetation.

Replacing dark pavement with lighter-colored paving could also have a positive effect. Indeed, technology to make lighter pavement exists. But this is also a long-term solution and requires significant capital outlays for somewhat minimal benefit.

However, replacing dark roofing with light reflective cool roofing provides the biggest bang for the buck. By raising reflectivity, we can offset the warming impact. Relative to other possible mitigations measures, it is easy to accomplish, relatively inexpensive, and provides immediate benefits to lessen the impacts of heat islands on a heating planet.

How Cool Roofing Systems Are Rated

Following the long trend toward verifiable results that has arisen in the sustainable building industry, the Cool Roof Rating Council (CRRC) was created in 1998 "to develop accurate and credible methods for evaluating and labeling the solar reflectance and thermal emittance (radiative properties) of roofing products and to disseminate the information to all interested parties."^{ix}

To become certified by CRRC, manufacturers must have their products tested and rated. The U.S. Department of Energy's ENERGY STAR® program also offers a certification process for cool, reflective roofing.^x

BRIEF HISTORY OF MODERN ROOFING

For many decades, traditional asphalt roofing construction was the norm. Asphalt roofs experience little expansion or contraction, which means there were no thermal shock issues to consider. There was little concern

for insulation and heat loss. Air-conditioning use was minimal or was not very costly. Therefore, summer heat retention was of not much concern.

Single-ply membrane products appeared in the early 1970s. Over the past few decades, scientists and product manufacturers developed better knowledge of chemical interactions and have introduced plasticizers and stabilizers into single-ply membranes, which prolong material life. At this point, the single-ply roofing industry has a proven performance record of more than 30 years.

As with any product, the quality of the components affects overall performance.

TYPES OF MEMBRANE ROOFING

There are more types of membrane roofing than many architects realize. Modified bitumen, for example, is asphalt-based and blended with styrene-butadiene-styrene or atactic polypropylene. This product is a hybrid of traditional BUR (built-up roofing).

Thermoset membranes are "vulcanized," which means the molecules are cross-linked, making polymers elastic. However, these materials become "set" so they are difficult to bond to each other. That means they cannot be softened and bonded by heat. Therefore, seaming requires adhesives. These include EDPM, Neoprene, and CSPE (Hypalon).

Thermoplastics will "flow" when heated because the molecules are not cross-linked. That means the seams can be heat welded or solvent welded. Ingredients used in compounding can include PVC resin, plasticizers, stabilizers, pigments, and fillers. These materials are represented by a somewhat bewildering array of abbreviations: PVC, CPA, EIP, NBP, CPE, PIB, and TPO.

The big players of thermoplastics, however, are TPO (thermoplastic polyolefin) and PVC (polyvinylchloride).

TPOs are relatively new in the field, with most having been installed in the past 15 years. The ASTM standard for TPO is ASTM D 6878-03 for TPO Based Sheet Roofing.

PVC MEMBRANES

PVC roofing membranes have a much longer history than TPO roofing. PVC's were introduced in Europe in the early 1960s and a decade later in the United States. PVC roofing systems can be installed on virtually any type of structure in any geographic location. Installations may be on dead flat, low-slope or sloped applications.

PVC roofing systems can be installed on virtually any type of structure in any geographic location. Installations may be on dead flat, low-slope or sloped applications. Of course, it is always good roofing design and installation

practice to make sure that water drains properly. However, because vinyl roofing uses no adhesives for seaming and is impervious to water, standing water that frequently occurs on flat roofs will not compromise the integrity of most vinyl systems.

PVC membranes are flexible and lightweight. Because of this, they can be custom-made to fit each roof and can be easily prefabricated. Prefabrication of deck sheets and flashing components entails doing a portion of the manufacturing in a controlled environment; this leads to fewer installation failures.

And PVC membranes are lightweight, which means they can be added to an existing roof without any need to modify the roof's structural system. This means that in many instances tear-off and disposal of the existing roof can be avoided.

Perhaps of most significance, vinyl roofing is continually heat-weldable. It is common knowledge that heat-welded seams are the most reliable, avoiding the potentially weak link of adhesives used in some systems. Being continually heat-weldable allows PVC to be easily repaired and patched.

Heat-seaming completely eliminates adhesive-related seam failure and leaks.

Some PVC roofing systems have two-way venting, which allows the roof system to "breathe" and helps with wind uplift. As an added benefit, this ventilation may help with the release of trapped moisture from the deck and building interior.

Roofs are commonly exposed to such substances as bird droppings, cooking grease, furnace residue, incinerator ash, acid rain, and seawater. While these are more common, there is an amazing variety of other less-common substances that can be particularly damaging to some roof systems.

Vinyl membranes are also highly resistant to most chemicals and harsh environments that roofs are subject to. A high level of weatherability means less roof replacements are required over the life of the building.

And, of course, most PVC membranes can be made white in color, which makes them highly reflective and very effective as cool roofing products.

SAFE FOR OCCUPANTS AND THE ENVIRONMENT

Despite lingering misperception and long-debunked misinformation, PVC roof systems are indeed safe for building occupants and the environment.

According to Dr. Patrick Moore, a co-founder of Greenpeace: "...PVC's effects on health and the environment have been investigated at every stage from manufacture through use and on to final disposal. In all



Photo courtesy of Duro-Last, Inc.

There is a long-debunked perception that vinyl is harmful to building occupants. It is not. And its clean installation is considered safer than roofing systems involving tar and hot pots. A vinyl roof was installed on Tulia High School in Tulia, Texas.

cases, vinyl has been shown to be safe and environmentally sound."

Consider the sustainable assets. During installation, no danger exists from flames, kettles, or hazardous fumes that could cause disruptions to business or result in irritation to building occupants. This is especially impactful for roofing and re-roofing projects at schools, daycare centers, hospitals, nursing homes, or other buildings occupied by young, old, or sick people.

Vinyl has been subject to more study and research than any other plastic material. PVC is produced in closed-loop manufacturing processes that are tightly monitored and controlled by the Occupational Safety & Health Administration (OSHA), the Environmental Protection Agency (EPA), and other regulatory bodies.

Vinyl is actually used in a variety of ways to help protect the environment, such as with landfill and livestock waste-pit liners, and chemical containers.

The list of entities affirming PVC safety includes U.S. Centers for Disease Control, Lawrence Berkeley National Laboratory, U.S. Department of Health & Human Services, U.S. Food and Drug Administration, U.S. National Academy of Sciences, and the U.S. Consumer Product Safety Commission.

INSTALLATION CONSIDERATIONS

Perhaps one of the reasons PVC thermoplastic single-plies have grown so much is because of their versatility. There are several methods that vinyl roofing systems can be attached.

Mechanically fastened systems offer straightforward, proven methods for meeting codes and look good. A key characteristic is that the installation process for mechanically fastened systems is not sensitive to jobsite conditions such as too hot, too cold, too damp, etc. This means they can be installed virtually any time of the year as long as the contractor is willing to work. As we know, there are contractors in places like Chicago, Illinois; Minneapolis, Minnesota; or Colorado who simply shovel the snow off the roof and go right on working in December, January and February. This method allows that, and could make a difference in your project meeting or missing deadlines important to the owner. Another benefit of mechanically fastened roof systems is that the membrane can be recycled.

Many specifiers choose adhered systems, as they can be aesthetically pleasing. Some drawbacks to adhered systems include installation restrictions due to weather conditions and the inability to recycle the roof membrane after its useful life due to the glues used during installation.

CASE STUDY: COOL COWS

Who would have thought that installing a cool roofing system on a barn would improve the milk production of cows? But that is exactly what happened in Chilliwack, British Columbia.

In 1980, dairy farmer John Wynker built a 31,000-square-foot barn to house his herd of 160 to 170 dairy cows. Over the years, the existing metal roof began to have issues. It contained a sprinkler system used to cool the barn and keep the temperature down for the dairy cows. Although the sprinkler system did not work well, it still helped lower the excess heat created from the metal roof. However, this sprinkler system and the failed metal roof produced other problems—multiple leaks.

Wynker needed a new roof that was durable, leak-proof, and would keep his cows cool, safe, and dry. Wynker contacted John Grimard, owner of J.G. Roofing in Chilliwack, who suggested installing a cool roofing system.

According to Grimard, the white membrane would be the perfect fit for the barn because it is durable, leak-proof, and virtually maintenance free. Plus, Grimard explained that the roofing system could save on energy costs for the barn during the summer months.

In addition, the manufacturer offers prefabrication, which means the majority of the membrane seaming could be done in a controlled factory environment. Thus the potential for rooftop installation errors and leaks would be reduced considerably. The membrane could be produced in prefabricated sheets of up to 2,500 square feet, which would make the installation easier and less labor intensive. That is even more important in times of skilled labor shortages, which are seen today.

Grimard's crew went to work. They re-roofed the barn without a tear-off, avoiding potential problems, such as accidentally dropping materials into the cows' feed, which could have proven harmful to the animals. The crew also added insulation and ventilation, and removed the old leaky sprinkler system, leaving only the existing fans in place.

Another benefit of the cool roofing system for the barn was its flexibility. A large barn tends to expand and contract with wind and temperature changes, and the membrane system allows this movement without jeopardizing the performance of the roof.

Shortly after the installation, Wynker discovered other benefits that surprised both him and Grimard. Just one week into the project, the herd's milk production increased to the point where the holding tank overflowed. Wynker determined that the increase was due to the cooler temperature in the barn. He found that in hot weather, his barn stayed cooler with the cool roofing system, which helped reduce the dairy cows' stress level and resulted in their giving more milk.

Plus, the farmer noted how quiet the barn was when it was windy or raining. "The old metal roof was always very noisy during bad weather," he says. During the winter months, the barn stayed warmer and prevented the cows' watering troughs from freezing.

The best news for Wynker? He saved money and received a leak-proof roof!

"In the first six months, I saved about \$22,000 in operational costs, and I attribute about 90 percent of that to the cool roofing system and the remainder to the added insulation," says the dairy farmer. "That translates into saving around \$44,000 a year, and my roof no longer leaks."



Photo courtesy of Duro-Last, Inc.

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MYTHS AND REALITIES OF PVC COOL ROOFING

Although modern cool roofing has been available since the 1980s, it is a new concept to some. The following are myths and realities about vinyl and cool roofing systems.

White Roofs in Cold Climates

Myth: White roofs do not save energy in the winter and cause energy to be lost.

Reality: While it seems that a material that keeps buildings cool in summer would do the same in winter, the reality is not so simple. The amount of heat a dark roof could potentially gain in winter really isn't all that significant compared to the amount of heat deflected in hotter seasons. Many environmental factors reduce the cooling impact of reflectivity in the winter. For example, the low angle of sun in winter allows for little solar heating potential. Plus, shorter and cloudier days reduce the

time that solar heating can occur. In northern climates, numerous days with snow cover turn any roof white. We use energy at different times of the day in the winter—with peak heating demand occurring after the sun goes down when residents are home. Many commercial buildings have relatively low heating energy demand compared to cooling demand due to the heat generated by human activity and equipment. Perhaps most significantly, the recent cost per BTU of energy to achieve a comfort level for cooling is higher than the cost per BTU to achieve the same comfort level with heating (natural gas: \$12.61/mil BTU; electricity: \$33.25/mil BTU; oil: \$18.53/mil BTU in order of heating source rank). As a result, numerous studies have shown that cool roofing leads to net energy benefits across the country—even in the far north. This reality was discussed in a scientific journal report titled "Bright Is the New Black," which concluded in part: "It has been shown...that in colder climates

during winter, lower emissivity may actually be a positive attribute for white roofs with respect to avoiding any possible winter heat energy penalty. If a performance standard for emissivity is set for roof membranes, the possibility that a low emissivity may be desirable in cold climates to avoid any winter heat penalty should be considered."^{xi,xii}

PVC Composition

Myth: Phthalates are harmful to health.

Reality: Without phthalates, PVC products are rigid like pipe. Phthalates are added to provide flexibility for such products as tubing, banners, tarps, and roofing membranes. In 50 years of study and use, phthalates have had a strong safety record. Based on reliable peer-reviewed studies, phthalates have never been shown to cause harm to humans when used as intended. "Human health effects from exposure to low levels of phthalates are unknown. Some types

of phthalates have affected the reproductive system of laboratory animals. More research is needed to assess the human health effects of exposure to phthalates.”^{xiii}

Former Surgeon General C. Everett Koop said that there is no scientific evidence that phthalates are harmful to children or adults. And Moore further stated that there is a significant risk in replacing phthalates with chemicals that have not been as thoroughly tested and found as safe.

Cool Roofing Colors

Myth: Reflective cool roofs can only be white.
Reality: White is the most reflective color, but cool roofs come in many colors with varying degrees of solar reflectivity. Darker colors can be significantly reflective by the use of pigments that absorb in the visible light spectrum (thus giving it a color) but reflect in the near-infrared spectrum that is not visible to the naked eye. Since nearly 50 percent of the sun's energy is in the near-infrared spectrum, cool colored pigments can be significantly more reflective than standard pigments.

Real Cost of Cool and Alternative Roofing

Myth: Cool roofing costs more than dark roofing.
Reality: Cool roofing incurs little or no increased costs. In fact, reflective roofing saves money over time. To determine the real cost of a roofing system, be sure to calculate all the factors, both up front and into the future.

ROOFING COST CALCULATOR

Factors to consider when comparing the total life-cycle cost of a cool PVC membrane roof versus an alternative roofing system.

Installation

- ✓ Roof product cost
- ✓ Installation costs
(labor and overhead)
- ✓ Tear-off costs (if required)
- ✓ Landfill costs
 - ▶ PVC roofs can be returned to the manufacturer and recycled after their useful life on a rooftop.
 - ▶ At least two PVC manufacturers have such programs.
- ✓ Building disruption costs

Long-term Durability

- ✓ Regular maintenance costs
(over 20 years)
- ✓ Roof replacement costs
(if life expectancy is less than 20 years)
- Repairs**
- ✓ Roof repair costs
(estimated over 20 years)



Photo courtesy of Duro-Last, Inc.

Studies show that cool roofing systems provide energy savings and other benefits when installed in cold climates. This cool roof was installed on West Shore Elementary School in Fenton, Michigan.

- ✓ Interior damage repairs
(estimated over 20 years)

Energy Savings

- ✓ Estimated energy savings
(over 20 years)
- ✓ Energy rebates/incentives

Warranty

- ✓ Cost for 15-year warranty

Insulation and Radiant Barriers

Myth: Increased insulation and radiant barriers provide the same benefits as cool roofing.

Reality: While other measures may also cost-effectively save energy within a building, they do not provide the area wide cooling of cool roofs that helps reduce urban heat island effects. Studies show that insulation and cool roofing are important partners in a sustainable and high-performing roof system. Substituting one for the other will likely lead to sub-optimal outcomes.

COOL VINYL ROOFING AND SUSTAINABLE BUILDING DESIGN

Vinyl may have a positive environmental profile when compared with other potential roofing materials. With metal, significant rock waste, tailings, and acid generation occurs from oxidation of sulfide materials during manufacture. The U.S. Environmental Protection Agency reported on this in a Technical Document titled: “Acid Mine Drainage Prediction.”^{xiv}

Galvanized metal roofing creates zinc discharge in storm water runoff. This was demonstrated in “A Survey of Zinc Concentrations in Industrial Stormwater Runoff” by the Washington State Department of Ecology.^{xv}

Clay tile requires massive excavation impacts, creating clay pits and soil erosion. A report the environmental impact of clay harvesting from the International Journal of Innovative Research and Development states that: “The effects generated from clay harvesting can be multiple, such as soil erosion, air and water pollution, geo-environmental disasters, loss of biodiversity, and ultimately loss of economic wealth.”^{xvi}

The issues with concrete are well-known. According to the EPA, “Cement plants are a significant source of sulfur dioxide, nitrogen oxide and carbon monoxide,” which are associated with a number of health and environmental impacts, including ground-level ozone, acid rain, global warming, water quality deterioration, visual impairment, and other impacts. These impacts were listed in a paper titled: “Cement Manufacturing Enforcement Initiative.”^{xvii}

Slate quarrying can cause broad environmental damage. According to guidelines from the Missouri Dept. of Natural Resources, “Rock quarry and stone operations deal with many things that can affect the environment. Materials such as dust, contaminated storm water and used oil can harm the environment and people if they are not properly managed.”^{xviii} Also, the report states, “Quarrying and stone

LEED CREDIT CATEGORY	REQUIREMENT
Sustainable Sites Credit 7.2: Heat Island Effect: Roof	Solar Reflectance Index of 78 (some systems exceed 110)
Energy and Atmosphere Prerequisite 2: Minimum Energy Performance	Comply with ASHRAE Standard 90.1-2004: If at least 70% reflectivity / .75 emittance may be able to reduce amount of insulation based on adjustment factors
Energy and Atmosphere Credit 1: Optimize Energy Performance	Reduce energy costs when compared to the energy cost budget of building's design; cool roofing reduces building's cooling load
Materials and Resources Credits 1.1 and 1.2: Building Re-Use of Walls, Floors and Roof	Extend the life of existing building, conserve resources, reduce waste and reduce environmental impacts; roof longevity extends the life of existing structure and HVAC equipment
Materials and Resources Credits 2.1 and 2.2: Construction Waste Management	Divert construction and demolition debris from disposal in landfills and incinerators; custom pre-fabrication virtually eliminates jobsite scrap
Materials and Resources Credits 4.1 and 4.2: Recycled Content	Use materials with pre- and post-consumer content; pre-consumer recycled into walkpads; post-consumer programs recycle roofs as flooring
Materials and Resources Credits 5.1 and 5.2: Regional Materials	Use building materials or products extracted or manufactured within 500 miles of project site; some companies strategically locate facilities within proximity of major markets
Indoor Environmental Quality Credit 2: Increased Ventilation	Provide additional outdoor ventilation to improve indoor air quality
Indoor Environmental Quality Credit 7.1: Thermal Comfort	Provide a comfortable thermal environment for occupants; cool roofing helps keep building cooler making HVAC more effective

processing facilities generate dust, also called particulate matter, with diameter less than or equal to 10 micrometers. Regulators call this dust PM10. PM10 can cause lung damage.”

One of the major sustainable benefits of PVC roofing is that it is inherently recyclable. Vinyl materials can be reprocessed and recycled repeatedly into useful products. More than one billion pounds of post-industrial and post-consumer vinyl is recycled annually in the United States, and that volume is growing.

PVC is the only roofing material proven to be recyclable on a large scale back into new roofing products. PVC roofing materials have been recycled in the United States and Europe for more than 20 years. Useful products such as commercial flooring, concrete expansion joints, and roofing walkpads are made from recycled vinyl.

LEED Credits

As the green movement grew, sustainability-minded architects and other stakeholders wondered how vinyl and PVC fit into the puzzle. The U.S. Green Building Council (USGBC) created a LEED Technical and Scientific Advisory Committee PVC Task Group that undertook a two-year study of PVC building products and determined that neither vinyl nor any competing material deserves to be eliminated. Regarding environmental impact, the final report states that: “The evidence indicates that a credit that rewards avoidance of PVC could steer decision makers toward using materials that are worse on most environmental impacts.”^{xix}

LEED CREDIT CATEGORY	REQUIREMENT
Sustainable Sites Credit 7.2: Heat Island Effect: Roof	Solar Reflectance Index of 78 (some systems exceed 110)
Energy and Atmosphere Prerequisite 2: Minimum Energy Performance	Achieve at least 2 points in EA Credit 1 (Cool Roofing reduces cooling load)
Energy and Atmosphere Credit 1: Optimize Energy Efficiency Performance	Demonstrate ENERGY STAR® energy performance rating of at least 69; efficiency in at least the 19th percentile; or follow LEED-EB Operations & Maintenance Reference Guide (Cool Roofing reduces cooling load)
Materials and Resources Credit 9: Solid Waste Management; Facility Alterations and Additions	Divert construction and demolition debris from disposal in landfills and incinerators; custom pre-fabrication virtually eliminates jobsite scrap
Indoor Environmental Quality Credit 1.3: Increased Ventilation	Provide outdoor air ventilation and improve indoor air quality; two-way breather vents keep negative air pressures and condensation in check

On human health risk, it states that: “Data on end-of-life emissions are highly uncertain and therefore there is a wide range of exposure possibilities.”

In fact, PVC cool roofing systems can help architects reach their LEED goals.

Some possible credit considerations for LEED-NC (New Construction) associated with a PVC cool roofing system include. With LEED v4 on the way, of course, some specific categories may change.

Some Possible credit considerations for LEED-EB (Existing Buildings) associated with a PVC cool roofing system include:

The Green Globes rating system includes a cool roof credit for roofs that have a minimum solar reflectance of 0.65 and a minimum thermal

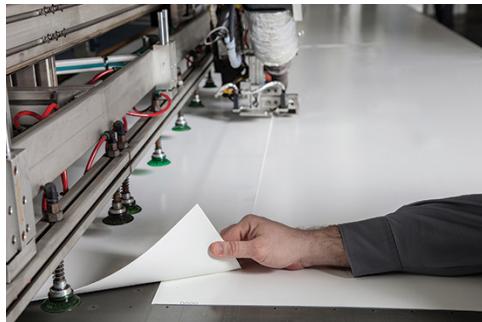
emittance of 0.90. One to 10 points are awarded based on the percent of the roof covered with cool roof material. A project can earn a total of 350 points in the Energy category, under a total of 1,000 points for the whole rating program. Further details on rating systems, codes, and standards are available on the website of the Cool Roof Rating Council.^{xx}

How to Select a Cool Roof

There are some key questions you should ask when deciding on the best system for your needs. You may have other considerations unique to certain projects, but these are critical:

- **Prefabrication:** Can the membrane and roofing accessories for penetrations be

Photo courtesy of Duro-Last, Inc.



When a cool roofing system is being specified, the ability of a company to prefabricate the system in a factory-controlled setting should be a factor. These prefabricated systems install quicker on site and require less on-site labor.

prefabricated? One of the biggest issues in construction today is a shortage of skilled labor. To be a truly durable and thus “green” system, it must be installed correctly with a minimum of installation errors. The extent of customization/pre-manufacturing the supplier or manufacturer can offer should factor highly in your specification. Does the performance of the whole system exceed the sum of the individual components? Do the components work in harmony?

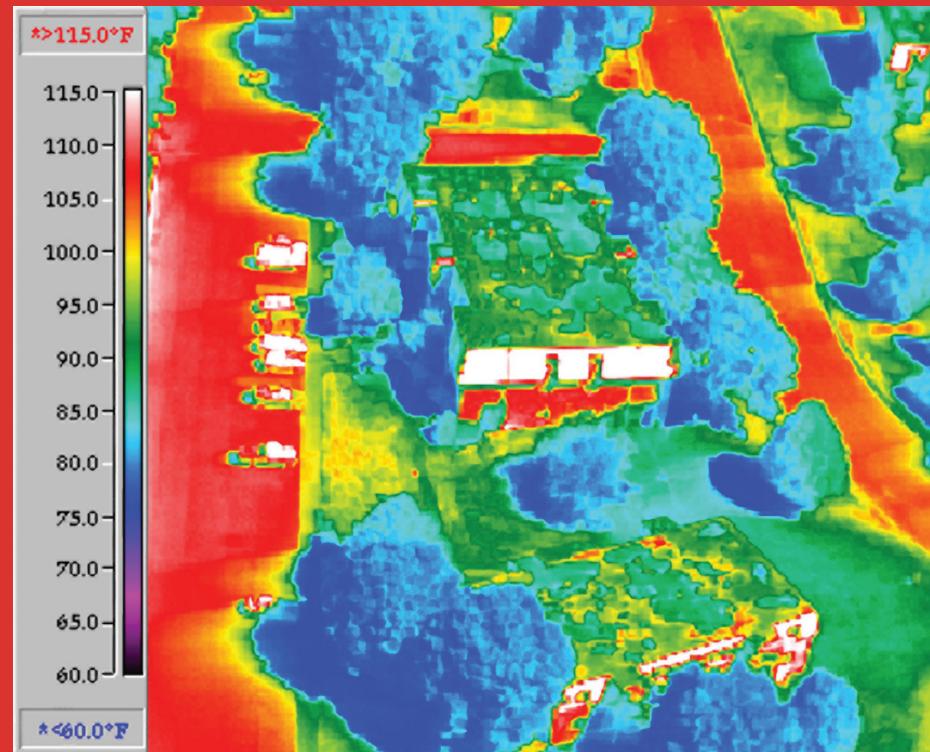
- **Membrane:** What is the base material made of? And how is it made? As noted earlier in the article, some materials have a lower carbon footprint, last longer, and provide more benefits. Will temperature, moisture, and dirt affect integrity? What are the code considerations? What is the impact of the weight of the roofing? Are there structural concerns? What are the aesthetic issues?
- **Complete Systems:** Are major components supplied by single or multiple suppliers? For the highest performance and lowest chance for error and incompatibility, a single supplier should supply all parts. This ties into a major movement in the increasingly complex world of building materials. Whereas past generations of architects, specifiers, engineers, contractors, and workers had a limited number of materials to deal with, new generations must contend with hundreds or thousands of materials and processes, some of which are not compatible. Systems manufactured or tested by a single supplier decrease that risk.
- **Flashing Methods:** What manner, method, and materials are used for waterproofing and attachment method(s) used at transition points with deck sheets, stacks, curbs, parapets, etc.? The quality of manufacture and installation are essential here. This is where most roofing failures occur

CASE STUDY: SUMMERFIELD APARTMENTS, NORTHFIELD, MINNESOTA

The impact of a cool roof is not apparent to the eye, but becomes clear with the help of infrared imagery.

The two images—a photo at the top, coupled with the thermal image of the same scene on the bottom—tell the story of how cool roofing in the form of white membrane keeps a building cool. These images record an urban scene in Northfield, Minnesota, on a fall morning at 11:26 a.m., following morning showers, when the outside temperature is 83 degrees Fahrenheit. The cool roof measures 89 degrees Fahrenheit, while the built-up roofing (BUR) has reached a blistering 115 degrees Fahrenheit. That’s 7 degrees Fahrenheit hotter than the 108-degree Fahrenheit temperature of a nearby asphalt parking lot.

Images courtesy of Duro-Last, Inc.



When these two images were created, the outside temperature was 83 degrees Fahrenheit. The top green square in the infrared image shows the temperature of a white membrane cool roof: 89 degrees Fahrenheit. The middle red square shows the temperature of a BUR roof: 115 degrees Fahrenheit. And the red showing the temperature of the asphalt road and parking is 108 degrees Fahrenheit.

due to expansion/contraction, building movement, and so on. Ask if the flashings are prefabricated in a controlled factory setting, which is the preferred method. Or, are they fabricated in the field, where errors can be more likely? Are the flashings integrated with the system? And of utmost concern: Are the flashings included in the warranty?

- **Warranties:** There is probably no other issue as controversial as warranty coverage. According to research, 77 percent of building owners say this is the most frequently unmet need (SPRI Research by Drucker Worldwide 2000). As the saying goes: “The large print giveth, the small print taketh away.”

For clues to the weaknesses of a system, look at the exclusions in the warranty. In particular, watch for fine print, which will suggest the weaknesses of the system. And what about extra costs? If there is no such thing as a free warranty, the question should be, “Why not?” Make sure the warranty can be transferred with ownership. Take note of exclusions. Some commercial roofing warranties specifically exclude ponding water on the roof, for instance. The length of time for the warranty should be realistic. If the company has only been in business for a few years or only manufactured roofing materials, offering a warranty of several decades should raise red flags of skepticism. If the material has been in existence for a long time, and the company has a long history

and long track record, the warranty will have more meaning. Another consideration when researching warranty coverage is the manufacturer’s care and maintenance guidelines. Be sure to request a copy and review it before making a purchase because some manufacturers require extensive care and maintenance for their warranties to remain valid.

- **Services Available:** Finally, what services does the manufacturer or supplier offer the architect? Manufacturers work with the designers to provide the best solution for each roofing need. These services could also include code information, drawings, and documentation. Your goal is to serve your clients with most clarity and with least liability.

CONCLUSION

Architects have long been leaders in reducing the heating and air-conditioning burdens caused by buildings. Installing a cool, reflective roof deflects solar heat from reaching into the building, thus reducing cooling needs. The use of PVC for the membrane adds to the sustainability of the roof by providing a long-lived material that will not only last up to 20 years or longer, but can be recycled at the end of that use. The use of a PVC membrane for a cool roof system can go a long way in meeting the goals of a sustainability-minded architect or specifier.

END NOTES

- ⁱ<http://climate.nasa.gov/causes/>
- ⁱⁱ<http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf>
- ⁱⁱⁱhttps://en.wikipedia.org/wiki/Intergovernmental_Panel_on_Climate_Change
- ^{iv}http://duro-last.com/pdf/marketing/dl_university/whitepapers/peak_demand_article.pdf
- ^v<http://www.coolrooftoolkit.org/wp-content/uploads/2015/07/Princeton-Paper-1-experimental-as-published-1.pdf>
- ^{vi}<http://www.greenspacehealth.com/wp-content/uploads/2013/01/urban-heat-island-epa.jpg>
- ^{vii}<https://heatisland.lbl.gov>
- ^{viii}<http://www.greenbuildingsolutions.org/Main-Menu/Home/Modern-Materials-Archive/Energy-Efficiency/The-Cool-Roof-Phenomenon.html>
- ^{ix}<http://coolroofs.org>
- ^x<https://www.energystar.gov/productfinder/product/certified-roof-products/>
- ^{xi}<http://iopscience.iop.org/article/10.1088/1748-9326/7/1/014029/meta;jsessionid=2B65F8F3857B40DEA1656521FFAB705B.c5.iopscience.cld.iop.org>
- ^{xii}<http://www.nasa.gov/topics/earth/features/ny-roofs.html>
- ^{xiii}http://www.cdc.gov/biomonitoring/Phthalates_FactSheet.html
- ^{xiv}<http://water.epa.gov/polwaste/nps/upload/amd.pdf>
- ^{xv}<https://fortress.wa.gov/ecy/publications/publications/0603009.pdf>
- ^{xvi}http://www.academia.edu/10257976/Environmental_Impacts_of_Clay_Harvesting
- ^{xvii}<http://www2.epa.gov/enforcement/cement-manufacturing-enforcement-initiative>
- ^{xviii}<http://dnr.mo.gov/pubs/pub340.pdf>
- ^{xix}<https://www2.buildinggreen.com/article/usgbc-releases-draft-report-pvc>
- ^{xx}http://coolroofs.org/documents/Cool_Roof_Ratings_Codes_and_Programs021710.pdf



Known as the “World’s Best Roof®,” a Duro-Last® roof is perfect for any flat, low-sloped, new or retrofit application. Precision-fabricated accessories combined with prefabricated deck sheets or roll goods allow for a watertight roof that doesn’t sacrifice aesthetics. www.duro-last.com

To receive AIA/CES credit, you are required to read the entire article and pass the test. Go to ce.architecturalrecord.com for complete text and to take the test. The quiz questions below include information from this online reading.

- 1. According to NASA, the world's leading climate research agency, what percentage of climate scientists agree that climate-warming trends over the past century are very likely due to human activities?**
 - A. 67 percent of climate scientists agree
 - B. 77 percent of climate scientists agree
 - C. 87 percent of climate scientists agree
 - D. 97 percent of climate scientists agree

- 2. Which entity certifies cool roofing systems?**
 - A. Cool Roofing Rating Council
 - B. ENERGY STAR®
 - C. Both of the above
 - D. None of the above

- 3. How is a cool roof achieved?**
 - A. A standard roofing system is upgraded with at least 6 inches of dense insulation.
 - B. Cooled air is pumped into a 4-inch gap beneath the roof deck.
 - C. The roof deck is reinforced with a second layer of OSB and a layer of closed-cell rigid foam board.
 - D. The roofing membrane is a light-colored, reflective roof surface that reflects and drives solar heat away from the building and into the atmosphere or beyond.

- 4. Which standard has the most rigorous requirements for minimum cool roof reflectance?**
 - A. ASHRAE 90.1 Energy Standard for Buildings (2011)
 - B. International Energy Conservation Code (2012)
 - C. ENERGY STAR® for Roofs (U.S. EPA, 2012)
 - D. All have equal reflectance requirements

- 5. A down side of cool roofing is that the roofing insulation performs better the hotter it gets, and as cool roofing keeps the roofing assembly cooler, the insulation performance suffers.**
 - A. True
 - B. False

- 6. Less vegetation in the urban land compared to rural land accounts for 56 percent of the 7- to 10-degree heat island difference between urban and rural areas. Which of the following causes 38 percent of the heat island effect?**
 - A. Dark paving
 - B. Dark roofing
 - C. Commercial building mechanical exhaust
 - D. None of the above

- 7. Who made the following statement: "...PVC's effects on health and the environment have been investigated at every stage from manufacture through use and on to final disposal. In all cases vinyl has been shown to be safe and environmentally sound."?**
 - A. Dr. Patrick Moore, co-founder of Greenpeace
 - B. David Gottfried, founder of the U.S. Green Building Council
 - C. John H. Adams, founding director of the National Resources Defense Council
 - D. Stephen E. Sandherr, CEO of Associated General Contractors

- 8. Logic suggests that if reflective roofs save energy in the heating months, they will then cost the same amount of energy in the cooling months because the reflective roof will not absorb any available heat. Why is that not accurate?**
 - A. The low angle of sun in winter allows for little solar heating potential
 - B. Shorter and cloudier days reduce the time that solar heating can occur
 - C. The recent cost per BTU of energy to achieve a comfort level for cooling is higher than the cost per BTU to achieve the same comfort level with heating
 - D. All of the above

- 9. Reflective roofing is only considered a cool roof if it is white.**
 - A. True
 - B. False

- 10. After dairy farmer John Wynker upgraded the leaky roof on his 31,000-square-foot barn to a cool roofing system, he saved \$22,000 on energy costs in the first six months. What percentage of this savings did he attribute to the cool roofing?**
 - A. 30 percent
 - B. 80 percent
 - C. 90 percent
 - D. 100 percent