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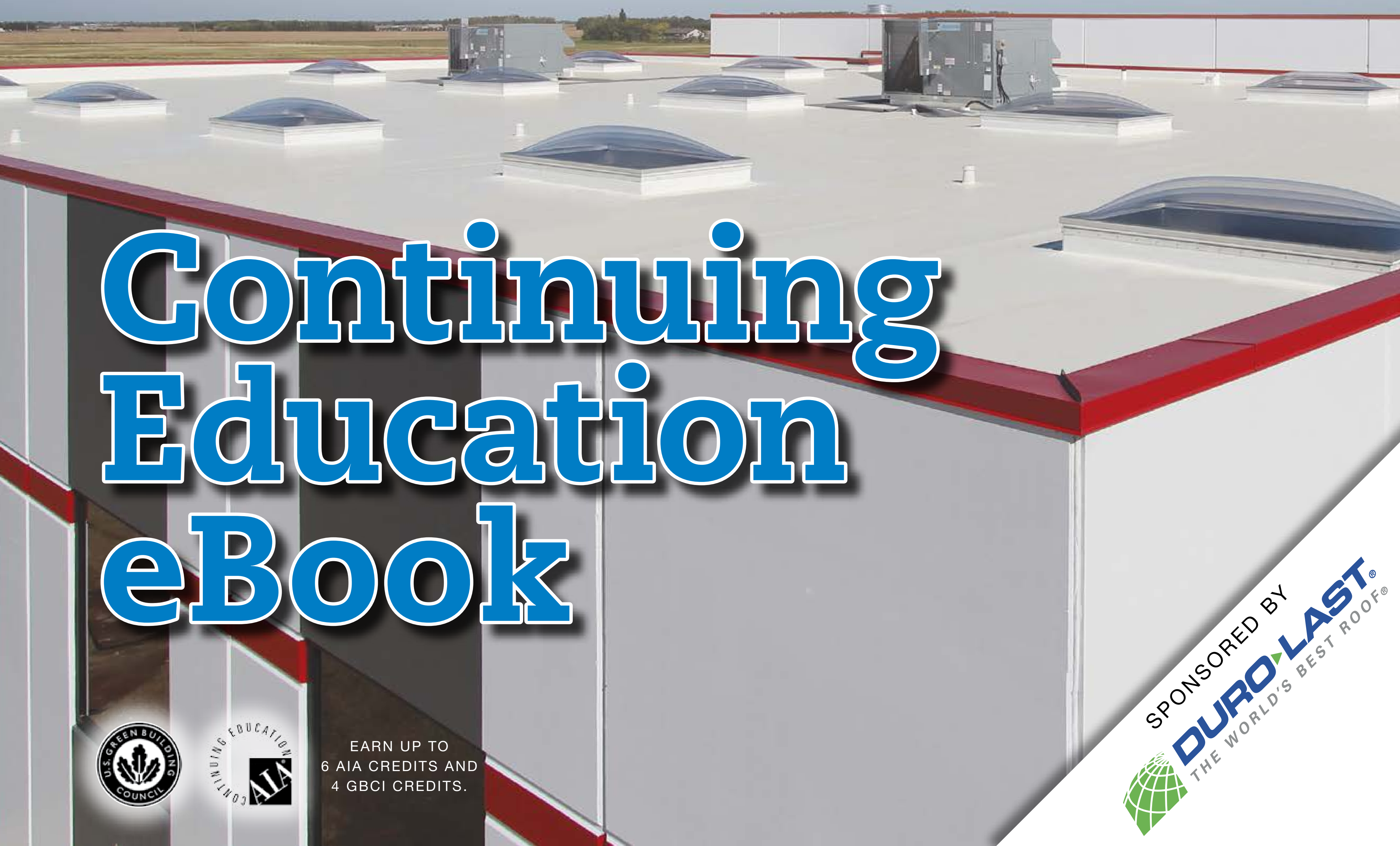

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Lindsay Lewis
Editor
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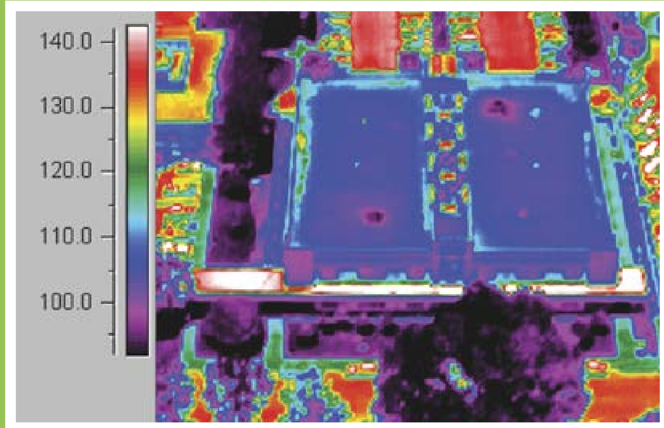
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Labor Shortage Solution — Specifying a Factory-Made Roofing Membrane

PREFABRICATED MEMBRANES AND CUSTOM PREFABRICATED ACCESSORIES INCREASE A ROOF'S QUALITY AND DURABILITY

By Kathy Price-Robinson | All images courtesy of Duro-Last

In a perfect world, the architect designs a building and the contractor builds it, accurately and on time, with all the skilled labor necessary.

In the real world, the supply of skilled construction labor ebbs and flows. Today it has ebbed. The scarcity of skilled labor drives up costs and drives down quality as crews rush from project to project in a quickening market.

Learning Objectives

After reading this article, you should be able to:

1. Discuss the decline of skilled building labor in the United States and its effect on building quality and durability.
2. Explain the history and benefits of a controlled factory setting for building components that decrease faulty onsite installation.
3. Discuss studies of roof failures that show that most moisture intrusion and uplift problems occur because of installation errors.
4. Describe how single-ply membrane roofing assemblies work for quality control and increased durability.
5. List case studies where prefabricated membrane roofing saved labor time on-site, decreased disruptions to building occupants, and increased durability of the roof and health and comfort for the occupants.

Many skilled workers left the building industry during the downturn and never came back.

A recent survey released by the Associated General Contractors of America revealed that 83 percent of construction firms struggle to fill positions for qualified craftworkers, carpenters, equipment operators, and laborers. Roofing labor shortages were a problem for 64 percent of firms surveyed.

This article is about how skilled labor shortages are affecting construction timetables and quality, with a focus on the roofing industry, and how a solution that architects can specify—factory-controlled, prefabricated membrane roofing systems that install on-site in a fraction of the time and with fewer workers—is helping to solve the problem.

The Decline of Skilled Building Labor

While the construction labor shortage has been many years in the making, it has recently received wide attention.

- A recent headline in *The Atlantic* reads: "Where Have All the Construction Workers Gone?"
- A headline in *Engineering News Record* reads: "Contractors Turning Down Work Due to Labor Shortages."
- Even back in 2013, a Forbes.com article rang the warning bell with the headline: "As Construction Begins Rebound, Looming Labor Shortages Raise Concerns."

With the recent upturn in the construction industry, unemployment levels for construction trades are at their lowest level in a decade and a half.

"Expanding job opportunities throughout the economy make it increasingly difficult for contractors to find experienced construction workers," Ken Simonson, the chief economist of the Associated General Contractors of America, notes in a press release.

"This scarcity shows up in record workweeks for craft workers and flattening of employment totals despite higher construction spending," Simonson adds.

Recent Census Bureau data on construction spending indicates there is robust demand for new construction, particularly for apartments and private nonresidential projects.

However, Simonson warns, "Some projects may be delayed or put on hold without new measures to recruit and prepare future workers."

The Ebb and Flow of Construction Labor

There are several reasons why construction labor decreased.

- **Fewer unions, fewer union apprentices.** The percentage of workers belonging to a union in the United States peaked in 1954 at almost 35 percent and the total number of union members peaked in 1979 at an estimated 21 million. Membership has declined since, with private sector union membership beginning a steady decline that continues into the 2010s, even while the membership of public sector unions grew steadily. Today, union membership is down to 11 percent overall. Traditionally, unions have operated training and apprenticeship programs, therefore with decreasing union power comes decreased worker training.
- **Dismantling of vocational and technical education.** Decades ago, vocational and technical education was a viable and popular path for high school students not headed to college. However, in efforts to send nearly every student to college, much of that vocational funding has been shifted to college-preparatory programs.
- **In economic downturn, workers left construction field.** As the Forbes article noted, "Hundreds of thousands of workers left the field in the downturn, changing career paths or retiring altogether. Young adults haven't clamored to enter the field and even for the ones that have, training programs have shrunk or evaporated altogether."
- **Changes in immigration policy.** According to the Bureau of Labor Statistics, 53 percent of roofers today are Hispanic, with a large number of that population being immigrants. Legal immigration for people in jobs like roofing, which is a skilled trade but doesn't require higher education, is becoming increasingly difficult.

Roofing Industry Affected

In the roofing industry, labor shortages rank as a top concern for contractors. According to the most recent State of the Industry Report from *Roofing Contractor* magazine, business is good but labor shortages are tempering the growth.

"The past recession has put us in a tough spot. We lost a generation or more of trained workers in our industry," Kent Schwickert, senior vice president, national business unit - Tecta America Corp., tells the magazine.

"An extreme labor shortage is going to impact the entire country, in my opinion. This is going to drive up wages and make competition for experienced roofers fierce," says Scott Baxter, a commercial sales manager for Interstate Roofing Inc. in Portland, Oregon, in an interview with the magazine.

One solution noted in the report is factory-made roofing systems to minimize labor needed in the field.

Roofing Problems and Faulty Installation

The shortage of skilled roofing workers is particularly concerning when the impact of roofing failures is examined. We'll discuss later in the article how and why faulty roofing installations lead to massive and costly building failures. But suffice it to say that a failed roofing system has far greater implications than sloppy interior trim work, for instance, or sloppy drywall finishing. While those installation failures may well stem from a similarly debilitating shortage of skilled workers, the outcomes are not likely as consequential as those caused by a poorly executed roofing job.

Roof installation is unique in the construction industry because it is one of the only building components that is partially or fully constructed on the jobsite. This means that the performance of the roof—which is a building's defense against the elements—relies heavily on the workmanship used to complete the installation.


Membranes up to 2,500 square feet can be prefabricated in a factory setting.

Many rooftop problems are caused by installation workmanship, not material failure. The most common installation errors include:

- **Improper Fastening.** Fasteners are installed at specified intervals, depending on the height of the roof and wind speeds, to reduce flutter and properly absorb the load. Not installing fasteners correctly can cause individual fasteners to fail, putting increased pressure on the remaining fasteners and eventually causing the entire roof to fail.
- **Flashings.** Precise workmanship is required at all roof penetrations or transitions. These are the most critical

areas of a rooftop and failure to properly seal these areas can lead to leaks and deterioration of the entire roof.

- **Perimeter Edges.** In addition to the membrane, proper installation of edge metal terminations is equally important. Recent statistics estimate that more than half of all roof warranty claims are attributed to metal edge failures.
- **Lack of Code Knowledge.** Another downfall of using unskilled laborers is that they often lack knowledge of local building codes, which vary greatly around the country and change depending on the building's location, height, and if it is located in a high wind zone.

Labor Shortage Solutions

Leaders in the construction industry have presented logical solutions to the skilled labor shortage. The Associated General Contractors of America (AGC) suggests several strategies in a report titled: "Preparing the Next Generation of Skilled Construction Workers: A Workforce Development Plan for the 21st Century." It suggests:

- Reform and reinvigorate the Carl D. Perkins Career & Technical Education Act, which is the primary federal funding vehicle for career and educational programs;
- Encourage private funding for craft training programs;
- Improve the Workforce Investment Act;
- Make it easier for veterans to get training and to be hired;
- Encourage partnerships between registered apprenticeship programs and community colleges;
- Expand federal apprenticeship resources and collect more comprehensive data on all apprenticeship programs;
- Enact immigration reform;
- Offer community college career and technical programs for high school students for free; and
- Make it easier to establish public schools focused on career and technical education.

For the Roofing Industry, Factory-Fabricated Systems Emerge as a Labor Shortage Solution

Certainly the ideas presented by the AGC, if enacted, would bring more trained construction workers into the industry. But the timeframe is long and the outcome uncertain.

However, innovation, as it often does, may provide a quicker solution. A case in point is the growing use of prefabricated, factory-made building systems that are brought to the site and installed in a fraction of the time of site-built systems.

This solution includes prefabricated roofing membrane systems that not only install on-site with an 80 percent to 85 percent reduction in on-site seam welding, but that also solve the problem of faulty sealing around penetrations, which as we'll see later on cause the most problems in roofing failures.

Factory-Made Building Components: A Long History

While prefab has become a buzzword in the past decade, the practice of specifying and installing prefabricated systems in buildings has quite a long history.

While specifying window systems is now normal, at one time it was common for window frames to be made and glazed on-site. Carpenters measured and cut the framing and trim members, assembled them, added glazing, and installed them into the window opening.

Cabinets were also once made primarily on-site. Eventually, factory-made cabinets, with all the quality controls inherent in such a manufacturing setting, became the norm.

Entire prefabricated houses go back at least until the 1850s, when the Loren iron house was prefabricated in England and shipped to Melbourne, Australia. It was moved to its current site in 1968.

Prefabricated homes became prevalent in England following World War II, when 3 million, or one quarter of the country's homes, had been damaged or destroyed. The post-war years brought a great need for housing along with a shortage of skilled building labor. Plus, empty factories once engaged in the war effort were ready for new products. The homes prefabricated in these factories and then shipped to the sites were designed to last 10 to 15 years, but a few of them survive today.

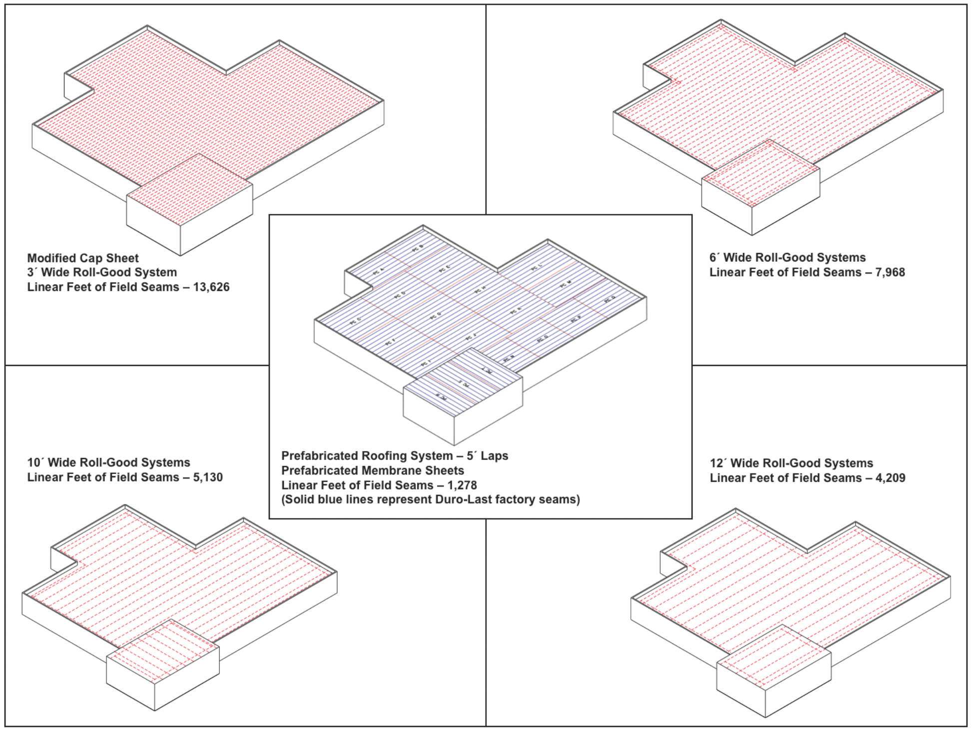
Some methods of easing on-site labor needs were a hybrid of site-built and factory controls. Kit homes popular in the early 20th Century were delivered to the site with each piece of lumber cut in a factory and numbered for quick assembly on the lot. This reduced labor and eliminated cutting mistakes.

Between 1908 and 1940, Sears, Roebuck and Co. sold and shipped more than 70,000 kit homes through its Modern Homes mail order program.

In 1927, for instance, The Sears, Roebuck and Co. kit house named the Vallonia bungalow cost from $1,500 to $2,500, depending on size. Delivered to the site were the pre-cut framing lumber, wood lath, millwork, doors, windows, roofing, siding, hardware, paint, etc. Plumbing, heating, wiring, and electrical were extra.

The prefabricated method of construction may have taken over the construction industry were it not for the Levitt Brothers, who transferred the genius of Henry Ford's assembly line for automobiles into the mass production of site-built homes. With the vast need for homes for returning veterans following World War II, the incredible efficiency of moving materials and skilled labor from house-to-house covering great tracts of land changed the home building industry. The mass produced site-built method became king.

It is, however, an incredibly inefficient and error-prone process.



When the vast majority of the seaming for a prefabricated membrane is done in the factory, it leaves very little to do on the rooftop. When the entire roofing system is fabricated on the rooftop, the number of seams to weld on-site increases dramatically.

Prefabricated System

A prefabricated system could include:

A. An insulation system and/or cover boards.

B. Roofing membranes that can be precision-fabricated to rooftop.

C. Curb, stack, parapet, and other flashings—made of membrane material in a factory—enable a watertight installation at critical roof transitions.

D. Edge details for an aesthetic and secure termination around the edge of the building.

"It's incredible that we're still building stick by stick on-site," says Bill Robinson, president of Train2Build and a moisture management expert based in New Orleans.

Recent decades have seen the prefab method of building rising once again. The oil embargo of the 1970s kick-started the movement to build energy-efficient homes, which brought about changes to construction methods and materials. Innovations by manufacturers brought further changes to "how things are done."

However, keeping up with current materials and methods is increasingly difficult in the great morass of non-unionized world of skilled construction labor. This can be concerning for architects, contractors, and specifiers, particularly as roofing is concerned.

Roofing Failure Consequences

Studies of roof failures show that many problems occur because of installation errors, particularly at changes in the plane on the roof, such as projections, curbs, drains, perimeters, and abutting walls.

It is often during forensic investigation of roofing failures that installation or compatibility errors are discovered. For single-ply membrane roofing, the errors can include open laps from improper on-site heat welding, loose flashings from improper on-site fabrication and installation, loose flashings from sealant failure, compromised flashings that are made of unreinforced membrane material, etc.

The consequences are immense. While exact statistics are difficult to come by because of out-of-court settlements, one industry source calculates that approximately 60 percent of litigation claims related to a building originate from the roof area. And that can be tough news for architects. High-profile litigation cases include:

- Architect Frank Gehry and a construction company were sued by the Massachusetts Institute of Technology for leaks, cracks, and drainage failure in MIT's $300 million Stata Center.
- Santiago Calatrava, a world-famous Spanish architect, faced legal action in 2014 from his native city of Valencia after the roof fell off the opera house he designed. Calavera faced more legal action from the owner of a winery with a persistently leaky roof.

When considering the design of imaginative buildings, it's hard to fault architects for their vision. As Frank Lloyd Wright famously declared, "If the roof doesn't leak, the architect hasn't been creative enough."

In most commercial building design, however, the design program is fairly straightforward. Still, a typical roofing installation presents craftsmanship challenges for the installers: on-site seaming, flashings of projections, edge details, and so on. If these challenges are not skillfully met, leaking problems will likely develop.

For the health of the building, as well as the health of designer's reputation and finances, specifications that remove potential problems are worth some consideration.

Factory Controls Bring Many Benefits

There are multiple benefits to fabricating components inside a controlled environment like a factory. The workers and materials are protected from weather, which means fewer lost days to snow, storms, or heat, and less damage to the materials because of weather.

The workers in a factory can be trained and supervised more easily. This means fewer construction defects, which means fewer building failures, lawsuits, and unhappy owners and tenants.

Recycling and reusing materials is more streamlined in a factory than on-site, where massive dumpsters filled with construction waste headed for a landfill are a common sight.

On the job-site, factory fabricated components, such as prefabricated roofing, means that the installation goes faster, and construction schedules get met. In the case of roofing, a custom prefabricated membrane means that workers spend less time on the roof itself, which translates to fewer jobsite accidents, and lower insurance premiums.

Factory-built components that were once cutting edge but have now become commonplace include:

A. Structural Insulated Panels (SIPs)
B. Precast concrete
C. Steel framing
D. Roofing trusses
E. Membrane roofing

For building owners and managers, custom fabrication of single-ply membrane roofing systems offers several advantages:

- Prefabricated roofing systems are easier to install throughout the year, even during adverse weather conditions. Installation time is reduced so the contractor can get on and off the job quickly. The relatively small amount of roof membrane seaming done in the field is completed with hot-air welding methods, which are virtually unaffected by cold or damp weather conditions.
- Single-ply roofing prefabrication dramatically reduces waste, both during the manufacturing process and installation. The roofing contractor orders the exact amount of roof membrane necessary for roof coverage, rather than a collection of raw materials.
- Prefabrication also appeals to engineers and architects who would like to address a particular structural or aesthetic design problem. Panel sizes, shapes, and colors can be pre-planned and prefabricated to achieve desired visual results.
- Finally, prefabrication allows the roofing contractor to take control of a construction operation in a highly unstable environment. Roofing contractors must plan their roofing projects carefully, and prefabrication affords greater worker productivity, a higher-quality installation, and potentially more satisfied customers.

How a Roofing Membrane Is Prefabricated in a Factory-Controlled Setting

Typically, a membrane manufacturer that offers prefabrication has an engineering services department to provide technical support, including CAD services, to create a roof customized to each building's specifications.

Membrane sheets are manufactured and inspected for quality control. According to the plans, membrane sheets are heat-welded together and prefabricated to dimensions as specified by the architect, specifier, or contractor. At least one manufacturer offers prefabricated panels up to 2,500 square feet.

In the factory, the membrane sheets are fitted with welded fastening tabs.

Fastening tabs are welded into the membrane sheet for attachment to the roof deck.

Orders are measured, squared up, and all seams are inspected before the membrane leaves the manufacturing facility. The custom-made pieces are then folded from fastening tab-to-fastening tab, with the goal of making unfolding easier and more straightforward for the installation crew.

Prefabricated membrane roofing companies may offer custom-made accessories for penetrations and details. Scuppers, pitch pans, and collector boxes eliminate the need for field fabrication and help increase installation efficiencies.

Factory-made edge metal can also be specified, designed, and delivered to the jobsite for a more precise installation that can prevent leakage troubles later on.

Finally, all pieces are rolled and shrink wrapped, ready for delivery to the site.

How a Roofing Membrane Is Installed

On-site, the full package of a custom roofing system is unwrapped. To begin, a prefabricated roof section is unrolled and positioned on the deck to expose the first securement tab. The securement tab is mechanically fastened to the deck with approved fasteners and stress distribution plates.

The roof section is then unfolded and pulled taut to remove any wrinkles exposing the second securement tab. This process is repeated until the entire roof section has been mechanically fastened to the deck, including all securement tabs and edges. The next section of roofing membrane is then positioned to provide a minimum of six inches overlap. The above procedure is repeated for each roof section.

Hot Air Welding

While 80 to 85 percent of welding is done in a factory-controlled setting, there is still welding to do on-site. The workers position the membrane so that the top membrane overlaps the bottom membrane, ensuring the welding area is dry, clean, and free of foreign material.

Workers then weld the top membrane to the bottom membrane using a handheld welder or an automatic welding machine, and silicone roller.

While up to 85 percent of the seam welding is done in the factory, the remainder is done on-site with an automatic welding machine, or a handheld welder, and a silicone roller.

Roof Penetrations and Prefabricated Flashings and Accessories.

A custom prefabricated flashing is made inside a factory controlled setting.

Stack flashing.

Two-way vent with skirt.

All field-welded seams must be inspected with a tack claw or similar tool (cotter key extractor), and all deficiencies repaired prior to inspection for warranty purposes.

Prefabricated flashings and accessories help ensure a leak-free finished product with less labor time on the roof.

Penetrations are to a roof what windows are to a wall. Both are of extreme value to the function of the building, yet they are vulnerable points in the structures that, if not sealed correctly, create pathways for unwanted, corrosive, and destructive water and air intrusion. Roof penetrations require extremely precise flashing and sealing. Even a slightly flawed installation on the rooftop could have massive implications later on.

As it is with vertical walls, transitions of any kind on a roof require the utmost attention and skills to avoid failure.

To save on labor demands on the roof, and to ensure quality control, prefabricated accessories are custom designed to fit each penetration. These include: pipes, drains, curbs, pitch pans, and expansion joints. For roofing systems that are covered under a thorough warranty, prefabricated flashings are often required.

Examples are:

Stack flashings for round penetrations are prefabricated with a reinforced roofing membrane. The installed roofing membrane is mechanically fastened around the penetration, then the flashing is placed, and the seam around the skirt is heat-welded to the roofing membrane for a waterproofing seal.

Custom fabricated two-way vent flashing with skirt. A two-way vent valve will allow for both exhaust and convective movement of air between breathers, and the cap prevents the entry of rain or snow. But if it is not flashed correctly, it will leak water into the building.

Prefabricated curb flashings are custom made to fit the units and features of each roof. The one-piece design


Prefabricated curb flashings.

eliminates the risk of several pieces cut for field fabrication and the potential for installation and sealing errors from piece-to-piece.

Other prefabricated accessories for quicker field installation and factory quality control include metal fascia covers, collector boxes with downspout, metal flange scupper, gutter systems, etc.

Conclusion

The shortages in skilled construction are real and many years in the making. While the finest minds in economics, labor, and construction are advocating for changes to build up a skilled workforce, that result will not manifest immediately. That means in a robust building environment, projects may be delayed or, worst yet, be constructed with flawed installation. For roofing, poor installation brings expensive damages, the exact causes of which can be difficult to determine.

Innovations by roofing manufacturers, particularly factory-fabricated roofing systems, can help ease problems caused by skilled labor shortages. Prefabricated membrane systems typically provide four main benefits:

- Factory-welded seams for better first-time quality and fewer callbacks
- Easier transitions for superior waterproofing and aesthetics
- Less labor required for the installation time on the roof
- Cleaner installations with less job-site waste and disruptions

As engineers, architects, installers, and owners realize the continuing benefits of specifying prefabricated buildings systems, the way buildings are constructed may well shift in favor of prefabricated systems for many decades to come.

CASE STUDY 1

A Revitalized Solar Roof for San Francisco's Davies Symphony Hall

San Francisco has long been known as a center for culture and the performing arts. Showcased by its War Memorial Opera House, considered the last Beaux Arts building constructed in the United States, this legacy continued with construction of the adjoining Louise M. Davies Symphony Hall. Opened in 1980 and renovated in 1992, its modern design was a collaboration of architects and acoustical engineers working in concert to create an intimate environment to enhance the music of the San Francisco Symphony and the beauty of the structure itself.

A few years ago, the San Francisco Public Utilities Commission (SFPUC) determined that installing a photovoltaic (PV) solar system on Davies Symphony Hall would benefit the

The 25,000-square-foot roof of the Louise M. Davies Symphony Hall in San Francisco was slated for a photovoltaic solar system. However, a deteriorating roof had to be addressed first.

Specifying a roof that would last as long as the overlaying solar array was the paramount concern.

people of San Francisco. The SFPUC retained engineering consultant AEPC of San Ramon, Calif., to design the PV solar system for the 25,000-square-foot roof.

The project team for the roof revitalization and PV solar system installation included Technical Roof Services (TRS) of Concord, Calif., and Fidelity Roof Company of Oakland, California.

Moisture Issues Emerged

Initially, the installation of a rooftop solar energy system seemed to be straightforward. However, significant moisture issues were discovered in the underlying roof insulation, contributing to deteriorating conditions in the 14-year-old tar-and-gravel roof.

"We knew the roof had some leaks and wanted to correct any problem areas before the solar panels were installed. Our goal was to ensure that the roof could last the life of the solar array, or a minimum of 25 years," says Venk Mani of APEC.

"We were aware of leaks in the exterior concrete walls but there had to be another source of wetting," adds Phillip Dregger of TRS. "The wet insulation on the roof just didn't follow any typical patterns."

After exhaustive testing, TRS and Dregger determined that there was substantial moisture leaking around the HVAC duct support posts that contributed to the saturation of the roof's insulation. It was clear that extensive repairs were needed, including replacing the 4,000 square feet of wet insulation, to protect the longevity of the new roof system.

The solar panel installation was the primary consideration.

"It's relatively expensive to turn off and disconnect a solar array and to repair the roof," Dregger explains. "Therefore, the owner required the roof life to match the service life of the PV system. In other words, they needed a new roof."

Options for Roof Ready for PV Solar

The SFPUC was presented with two available options:

A. Tear off the current roof and install a new one.
B. Overlay the existing roof with a new membrane.

The SFPUC opted to re-cover the existing roof as replacing the old roof would take longer and interfere with the symphony's rehearsal and performance schedule.

After evaluating the available membrane alternatives, Dregger recommended a white 60-mil-thick thermoplastic PVC roof system.

"Dealing with the dust, debris, odors, and noise would be important considerations on this project," he explains. "The PVC roof membrane would be quicker to install. Additionally, we needed to mechanically attach the cover board and new roof membrane through the existing roof down to the concrete deck."

Material Prefabrication Expedited Installation

Prefabrication was another advantage of the roofing system selected. The membrane was prefabricated into rolls that were 22 feet wide, reducing the application time and on-site welding.

In addition, the penetration flashings, parapet wall membrane, membrane curbs, solar hold down boots, and other related roof materials were all custom fabricated at the factory. This not only assured installation accuracy at changes in plane on the roof, such as projections, curbs, drains, perimeters, and abutting walls, but of equal importance was the roofing company's ability to expedite the installation process and meet critical deadlines.

Solar Ready

The first step in the roof overlay process was to remove the existing gravel from the built-up roof as well as the wet roof and insulation areas. Once cleared, the design called for half-inch, high-density gypsum cover board to be mechanically fastened through the existing roof and insulation, to the concrete deck, which provided a smooth surface for the adhered 60-mil overlay membrane. This process assured the roof met wind uplift as well as seismic design requirements.

Working Around Rehearsals and the Streets of San Francisco

Scheduling commitments at a busy location in the center of the city meant that the materials and equipment could only be delivered and crane-loaded onto the rooftop on weekends.

Work schedules were adjusted to meet the symphony's pre-established rehearsal and performance requirements. This meant sometimes working late into the evenings and weekends to meet the scheduled completion. The on-site time and labor saved by the prefabricated roofing system helped keep the project on track.

The school board of the Joseph Kushner Hebrew Academy in Livingston, N.J., wanted a reroofing job quiet and safe enough to not disrupt classes.

CASE STUDY 2

A Prefabricated Roofing System Was Installed Relatively Quietly and Quickly

The EPDM roof was failing and nearing the end of its useful life on the Joseph Kushner Hebrew Academy in Livingston, N.J.

Multiple companies offered various solutions for re-roofing the facility. The reroofing project had been left open to bid for five years and the school board had many options to consider before awarding the work for the 200,000-square-foot project.

Because the re-roofing job was to be done over the existing EPDM system while school was in session, several factors had to be considered prior to choosing a bid.

Primarily concerned about the occupants of the building, the academy's decision makers wanted a roofing option that would not produce noise or fumes and would be completed within budget and in a reasonable timeframe.

Although other options were considered, a prefabricated single-ply membrane was chosen for several reasons: 1) Its clean and safe application method met the requirements necessary for maintaining classes during installation; 2) The membrane manufacturer offered custom prefabrication; 3) The mechanical attachment; 4) Competitive pricing; and 5) The 15-year warranty.

The membrane's high-reflectivity was also attractive to the board members, as it would save the school energy and money.

Scope of the Project

The job was enormous. It required flashing approximately 400 penetrations, including 126 HVAC units, on five different roof levels.

The flashings—made of membrane material that connects horizontal and vertical roof surfaces on rooftop protrusions such as curbs and stacks—are prefabricated in the manufacturer's plant, and then delivered to the jobsite. Had the flashings not been prefabricated, workers would have had to manufacture them on top of the roof, during installation, which could increase the risk of worker error and thus increase the chance of roofing failure.

Because so much of the roof can be manufactured in a controlled factory environment prior to on-site installation, roofing contractors can typically complete jobs more quickly and efficiently and with less disruption than contractors using other systems.

The re-roofing job required penetrations for about 400 penetrations, including 126 HVAC units, all on five different roof levels.

The reroofing job required penetrations for about 400 penetrations, including 126 HVAC units, all on five different roof levels.

The school board was impressed by the roofing contractor's ability to finish the job in just 60 days—less than the estimated timeframe—despite consistently poor weather conditions, which hindered the team's progress.

Prefabrication also helped provide the assurance of a roof that would be leak-proof and virtually maintenance free, and under the protection of a vigorous warranty.

Planning and Preparation Before Installation

In preparation for the large project, the owner of the roofing company spent three days on top of the roof with the membrane manufacturer's representative estimating the number of deck sheets that would be required. They also measured all of the roof's penetrations.

As part of the academy's roof replacement project, a uniquely designed pitched roof was installed on the front of the building, making the new roof impressive not only in terms of necessity and practicality, but also aesthetically.

Following the wishes of the school board, the installation team was successful in reroofing the Academy with no interruptions to classes. Staff and students held classes as usual inside the building during construction.

CASE STUDY 3

Time and Labor Saved for Church Re-roofing Project

At the Summerville Baptist Church in Summerville, S.C., ponding water on the gym's existing modified bitumen roof and the built-up roof on several classrooms had created leak problems. With the buildings in constant use, officials at the church worried an accident would occur where there was a leak, endangering the approximately 175 children that attended the church's daycare center.

The warranty on the new prefabricated membrane roof did not exclude ponding.

Dodging buckets or closing down the facility in order to make repairs on the roof were not options. At risk from water damage were office and school equipment such and the gym's brand-new parquet floor.

Roofing Systems Considered

Several types of roofing systems were reviewed during the initial phases of the re-roofing project.

"We looked at built-ups again, synthetic rubber, spray-on coatings as well as thermoplastic single-plies," recalls church maintenance director John Nettles. Officials at Summerville weighed their options and the benefits of each type of system before determining that a prefabricated membrane roofing system would be the best choice.

John Congdon, owner of Congdon Roofing, Inc. in Charleston, S.C., agreed: "We knew that the mechanically attached . . . single-ply roofing system would be a perfect fit for the Summerville Baptist Church facilities," Congdon says. "Both of these problem roofs had parapet walls to deal with. With the (membrane) roofing system, you can encapsulate the parapet walls to resolve leaking problems that normally occur in walls made of mortar."

On-Site Labor and Time Saved

Another benefit of the (membrane) roofing system is prefabrication. With 80 percent to 85 percent of the seams being factory welded at one of the membrane manufacturer's facilities, the Congdon Roofing crew had less rooftop field seaming to complete, thus making the roof easier and quicker to install with fewer hours of labor.

Congdon noted that the system is clean and uses no hazardous materials, which was important to church officials who did not want any messy tar kettles on the roofs or near the buildings that were occupied during the installation.

Plus, because the warranty on the prefabricated membrane roofing system does not exclude ponding water or consequential damages, church officials did not have to worry about the minor ponds associated with low-sloped roofs that had caused the previous roof to fail.

The church officials liked the new membrane roofing system so much that they recommended it to another nearby church that needed a new roof for its nursery building.

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LEED: The Next Generation

AS LEED'S MOST SIGNIFICANT UPGRADE SINCE VERSION 2.0 IN 2000, PROJECT TEAMS HAVE THEIR WORK CUT OUT FOR THEM TO MEET V4'S MOST STRINGENT REQUIREMENTS

By Barbara Horwitz-Bennett

Considered to be the most significant revamping of the LEED credit system, although not without its critics, many are applauding the new and improved v4 as raising the sustainable building bar and continuing to drive market transformation.

"This new version of LEED raises the thresholds in categories that truly needed change to maintain LEED's role as a leader in sustainability standards, as well as current reference standards," states Jeffery Saad, AIA, LEED AP, vice president, director of design, HKS, Chicago.

"While it has been a long time in development, including an unprecedented six comment periods, the end result is a robust, challenging and widely agreed upon step forward," agrees Courtney Lorenz, director of environmental management, Skanska USA, Durham, N.C.

By increasing energy and water efficiency thresholds and introducing a new Demand Response (DR) credit, for example, Saad sees LEED's overall focus as evolving from reducing negative environmental impacts to targeting zero impact.

Learning Objectives

After reading this article, you should be able to:

1. **Identify the underlying principles guiding v4's new prerequisites and credits.**
2. **Appreciate the fact that designers will have to be more resourceful and innovative to meet more stringent energy and water efficiency requirements.**
3. **Describe how v4 seeks to promote product transparency and its ramifications on the building products industry moving forward.**
4. **Explain the intent and goals of utilizing an integrative project process.**

In fact, LEED's underpinning structure has shifted from avoiding negative impact categories to improved environmental outcomes. Essentially, v4 will now evaluate building projects based upon their ability to: reduce its contribution of carbon emissions, enhance human health and well-being, protect water and biodiversity, promote regenerative resource cycles, build a green economy and support improved community level quality of life.

Considered to be more technically rigorous, v4 has rebalanced its point structure, assigning the highest values to credits that will most significantly further one of more of these aforementioned goals.

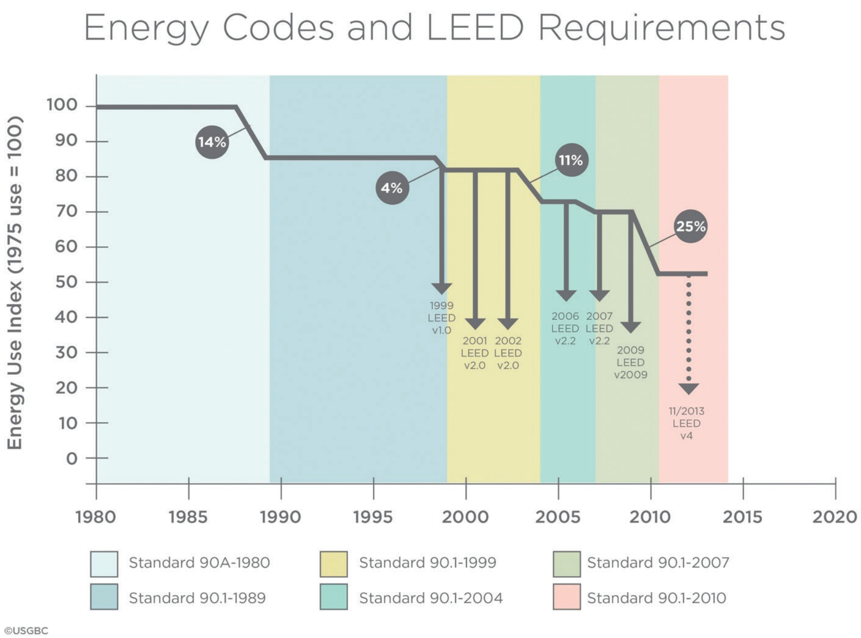
Other significant broad-scale changes include new market-specific rating systems, more simplified submittal requirements, enhanced reference materials and online tools, and more intuitive documentation forms. Now providing rating systems for 21 different building types, the USGBC has added data centers, warehouses and distribution centers, hospitality, existing schools, existing retail and mid-rise residential buildings to its LEED portfolio.

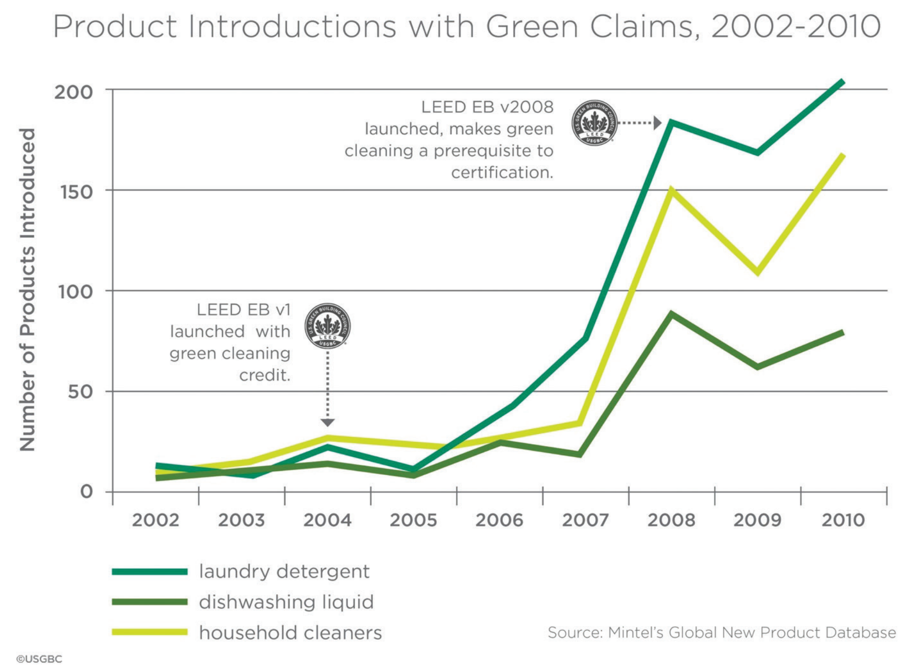
"I think the approaches of standardization, updating of credit weightings and increased building information management add up to a system that makes sense and makes a difference. It is a well-balanced step forward, with a mixture of familiar approaches and new 'reach goals'," says Lorenz.

"That being said, this has been the most highly contested version yet, so the speed at which all members of the green building community start to use this program will be an indicator of its success," he adds.

LEED v4's new and updated credits and prerequisites are guided by the following underpinning impact categories. Image courtesy of USGBC

Perhaps one of the more controversial changes has been the inclusion of Life-Cycle Assessment (LCA) data, as verified by Environmental Product Declarations (EPDs). Intended to significantly drive building product disclosure and transparency, specifiers and contractors are enthusiastically applauding this move, although many are nervous about the extent to which the building products industry will have to scramble to assemble, verify and publish the required data.





LEED has provided an avenue for codes to become more rigorous at a much faster rate, as shown here with increasing Energy Use Index levels of each ASHRAE 90.1 release directly corresponding to subsequent LEED versions. Image courtesy of USGBC

The introduction of new LEED credits can be directly linked to the availability of products to fulfill those requirements. As shown here, a spike in green cleaning products occurred shortly following the release of LEED-EB v2008, which made green cleaning a prerequisite to certification. Image courtesy of USGBC

"Rather than relying on single attributes of products—such as recycled content, biobased content or reused material—v4 encourages manufacturers and consumers to consider the product of material from the perspective of understanding life-cycle impacts, i.e. environmental, human and ecological impacts of production," explains Chrissy Macken, V4 assistant project manager, USGBC, Washington, D.C.

Life-cycle cost of a system is an important part of the equation when considering mechanicals, like a heating and cooling system. A geothermal heat pump system, while more expensive upfront, can more than pay for itself through reduced energy consumption, reduced maintenance, the ability to generate all or part of a building's hot water requirements and long system life. Add to that the available 10 percent federal tax credits and modified accelerated depreciation, and payback calculation can really be swift.

Market Consensus

As noted, the USGBC took its time with the development of v4 in order to solicit and consider a significant level of industry feedback. In particular, more than 23,000 public comments were registered from November 2010 to March 2013. Furthermore, the introduction of this most recent version, originally slated for 2012, was pushed back a year so that v4 could incorporate some of this important feedback.

"The process was completed in a consensus-building and transparent way that anyone in the building industry could follow," explains Andrew Zumwalt-Hathaway, USGBC LEED Faculty, LEED AP BD+C, director, sustainability consulting services, Steven Winter Associates, Norwalk, Conn.

In addition, a number of Technical Advisory Groups were established to seek input from a variety of industry professionals.

"I would say there are many who are not happy with v4 as it is, but the fact that people have been forthright in sharing their thoughts through the numerous commenting periods and getting their voices heard is a success story on how the building industry has been engaged in the entire process," states Judhajit Chakraborty, LEED AP BD+C, built ecology, WSP, San Francisco.

A Little History CONTINUED ON NEXT PAGE

Looking back at a decade and a half of LEED, pilot Version 1.0 was originally launched back in 1998. Significant modifications were then made to create Version 2.0, which was introduced in 2000.

Slowly, but surely, building teams began trying out the rating system as the number of LEED-certified buildings began to grow.

Version 2.1, with minor tweaks and changes came out in 2002, following by 2.2 in 2005. That year also marked the introduction of LEED Existing Buildings and LEED-Commercial Interiors.

LEED's next iteration occurred in 2009 with the release of 3.0. Although this version rebalanced the point system with 100 basic credits, offered bonus points for innovation and regional priority, and harmonized the template for the various market-specific rating systems, the actual credit requirements didn't change much.

Concurrently, as the sustainable building movement has taken off, the market has gotten quite good at delivering LEED buildings. In fact, more and more buildings are now certifying at the higher Gold and Platinum levels. And while the U.S. Green

In a similar vein, Russell Perry, AIA, LEED AP, co-director, sustainable design, SmithGroupJJR, Washington, D.C., relates, "many people certainly found that their concerns were not fully addressed, and I find myself among those, but on the whole, the dialog was rich and comprehensive. Nowhere in the industry were these issues more thoroughly vetted than in the various forums around v4. No other organization in the sustainable design world has the reach of the USGBC, and none can curate a dialog that is quite so lively."

Yet another tool which the USGBC deployed was the establishment of a Beta program where a couple hundred building projects tested out v4 and then provided feedback on how to make the new system more usable. USGBC then responded with corresponding revisions to reference guide.

Of course, v4 also taps into insights garnered from thousands of projects dating all the way back to LEED's inception.

"I think at the heart of it is more than 40,000 case studies of lessons learned that we've married with better understanding of interconnections of the built environment and the natural environment, a better understanding of the way that people engage with their physical environment and a better understanding of the way that technology has emerged to produce a rating system that ups the bar and encourages project teams to focus on and capitalize on the market transformation that we have brought to this point, but also encourages them to go further and faster and higher and deeper and broader," states Brenda Morawa, P.E., vice president, Integrated Environmental Solutions-North American Division, Atlanta, and LEED Implementation

A Little History continued from previous page

Building Council is thrilled about this, they also see this as a clear indication that it is high time to raise the bar and continue pushing the envelope.

As such, "v4 represents the largest change in LEED since we moved from the pilot to v2, back in 2000," states Mara Baum, AIA, LEED AP BD+C, senior associate, sustainable design leader, healthcare, HOK, San Francisco.

"I think this latest evolution of LEED is positioned very well to do what LEED always has strived for and succeeded at doing, turning best-in-class into status-quo," adds Curt Fessler, LEED AP BD+C, marketing director, Construction Specialties, Muncy, Penn.

To date, the U.S. Green Building Council has 77 chapters, 13,000 member companies and organizations and has been used in 145 different countries. In addition, more than 181,000 professionals hold LEED credentials.

Advisory Committee Chair in a USGBC webinar, "Key Concepts & Strategies, Introduction to v4."

Ultimately, v4 was approved by 86 percent of the consensus body, so the USGBC is confident that market adoption will be broad.

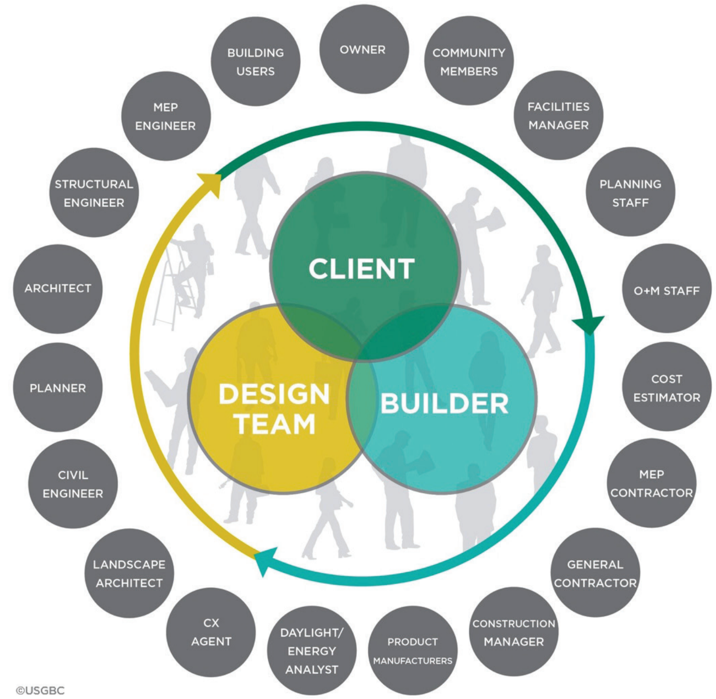
A Closer Look

Before delving into more details regarding v4's changes and how they will impact projects seeking LEED certification moving forward, it's important to note that the USGBC has opted for a gradual phase-in so that project teams have ample time to get up to speed on the new requirements. Consequently, projects will still be given the option to register under LEED 2009 until as late as June 2015.

At the same time, the USGBC anticipates that building owners will embrace v4 sooner as opposed to later.

"Organizations that want to differentiate themselves as continuing to advance the evolution of the green building industry are going to gravitate toward v4 because it's going to be a significant market differentiator," explains Brendan Owens, vice president, LEED technical development, USGBC, Washington, D.C., in the "Key Concepts & Strategies" webinar.

While a number of credits have been moved, renamed or combined, v4 does maintain the same structure and should be familiar to LEED users. At the same time, the new version places much more of an emphasis on accountability and performance verification.



Through an integrative project process, the building team collaborates early on with building users, facility managers and subcontractors to best capitalize on their specialized input and knowledge. Image courtesy of USGBC

Consequently, v4 directs the creation of feedback loops to make sure that the building is actually performing in line with the original design intent. For example, building-level energy and water metering have been upgraded to a prerequisite and a new Advanced Energy Metering credit requires metering of all energy end-uses representing 10 percent or more the building's total energy consumption.

"While in the past, project teams simply aimed to 'check the box' to obtain points, the changes to LEED in version 4 indicate movement toward more performance-based

Measured versus Proposed Savings Percentages

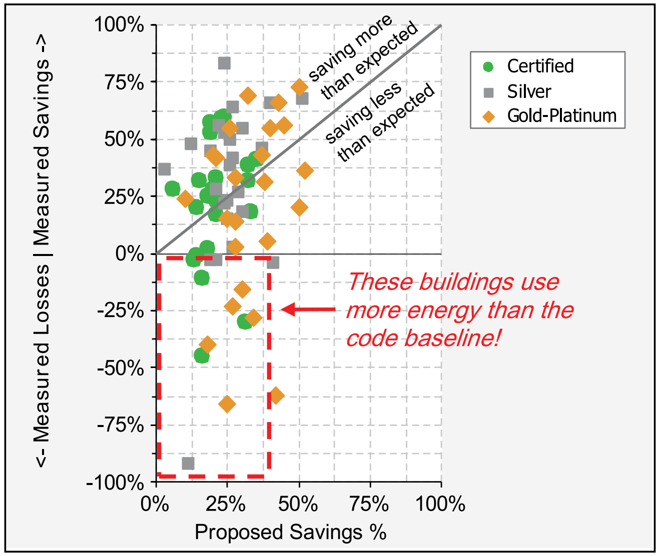
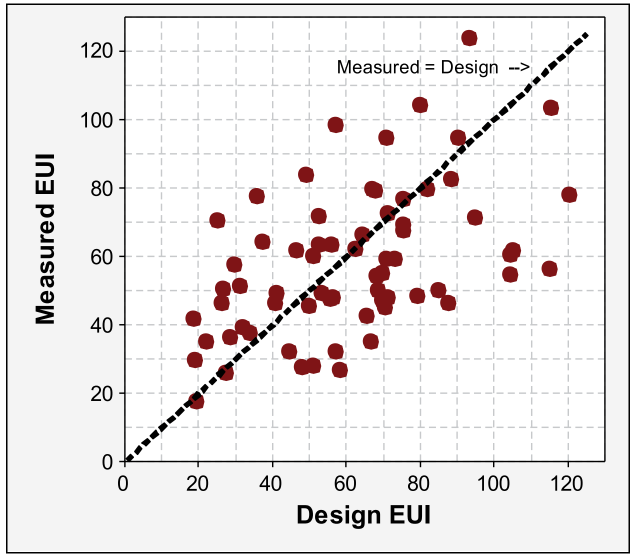


Figure ES-4: Measured versus Design EUIs
All EUIs in kBtu/sf



A quarter of sampled LEED-rated buildings were found to perform significantly below original design projections, according to a National Building Institute study. Image courtesy of the National Building Institute

criteria," explains Mark Rossolo, global director of public affairs, UL Environment, Portland. "It's focusing on the 'why' as opposed to the 'how.'"

Tougher Energy Requirements

Perhaps one of the most ambitious changes in the Energy & Atmosphere categories is the inclusion of ASHRAE 90.1-2010, in place of the previous 2007 version, and the fact that close to 20 percent of the system's credits are centered around energy-efficiency levels. And although the minimum energy cost savings threshold has been reduced from 10 percent to 5 percent better than 90.1-2010, in response to concerns that the originally proposed 10 percent was too aggressive, still, the new energy efficiency levels are quite high.

"That's probably the single biggest question I get from my clients," relates Chris Schaffner, P.E., LEED Fellow, founder, principal, The Green Engineer, Concord, Mass., in part II of the USGBC's Introduction to v4 webinar, "Performance: Measuring for Success."

"On average it's about a 20 percent difference in energy performance," he continues, "and people wonder how hard it's going to be to do this. I think the short answer is it's hard, but it's not impossible. Previously, the engineer could do a lot of the work and get you there, but now it really takes the whole team…everyone working together from the beginning."

Mara Baum, AIA, LEED AP BD+C, senior associate, sustainable design leader, healthcare, HOK, San Francisco, agrees that reaching this level of energy efficiency will require more innovation, but the building technologies capable of achieving these goals are not new or untested. For example, Baum anticipates seeing more systems that decouple heating and cooling from ventilation requirements as they tend to keep occupants more comfortable while using considerably less energy than equivalent all-air systems.

Incorporating a geothermal heat pump system is one way buildings can realize a 30 to 40 percent energy reduction versus the standard ASHRAE 90.1 building by allowing the natural and consistent temperature of the earth to do a large portion of the heating and cooling required.

Generally speaking, HKS's LEED Green Associate Branden Clements anticipates that designers will have to place a greater focus on systems working synergistically. For example, capturing waste heat with airside energy recovery systems and then reusing that heat. As a side note, he mentions that ASHRAE 90.1-2010 provides economizer exemptions if a specific efficiencies are reached, which offers greater flexibility to the designer.

"The HVAC systems are in for a major makeover under ASHRAE 90.1-2010," reports Chakraborty. "Reduced fan power, mandating economizers for almost all climate zones; energy recovery with as little as 30 percent outside air; limitations in reheat; increased chiller and boiler performance requirements; and mandating HVAC commissioning are a few of the new requirements. ASHRAE also calls for innovative ways to reduce fan power, encourages use of dedicated outside air systems and decreased reliance on constant volume systems, which are normally used in labs and hospitals."

In addition, under the LEED O+M rating systems, existing buildings seeking v4 certification will be required to achieve an ENERGY STAR score of at least 75.

Recognizing the limited opportunities that existing building's have in the arena of energy efficiency improvements, a new pilot credit called Energy Jumpstart offers and alternative path of basic certification for buildings which can demonstrate a 20 percent reduction over an established baselines during a 12-month period.

The increased energy performance requirements offered by LEED v4 are easily accomplished by using a water source heat pump system. The inherent recycling of energy through a water source system allows heat from one part of a building to be recycled and used in a different part of the building. For instance, often times the core of a building needs constant cooling even in winter months; the heat extracted from the core of the building can be transferred to the perimeter of the building and used to heat those spaces.

Some other HVAC technologies which designers expect to see more of include chilled beams, variable refrigerant systems, solar hot water heating, mechanical units and refrigeration equipment with higher SEER ratings, according to Lorenz.

On the Meter

As noted, metering and submetering technology will play a significant role in v4 rated buildings.

Emphasizing the very key role that metering plays in indicating if a building is actually performing in line with projections, Chakraborty points to an eye-opening New Buildings Institute study, "Energy Performance of LEED for New Construction Buildings," conducted back in 2008 and commissioned by the USGBC with help from the U.S. Environmental Protection Agency (EPA).[1]

In charting the measured versus modeled energy use intensity (EUI) of LEED-certified buildings, NBI discovered that while LEED-certified buildings were performing 25 to 30 percent better than the national average. But on the other hand, a decent percentage of certified buildings were not performing at the level to which they were designed.

In particular, measured EUIs for a quarter of the sampled projects were significantly worse than design projections with a number of those buildings even coming in below the energy code baseline.

With v4 buildings being held much more accountable for measured energy consumption, plug loads are going to become much more of an issue. In fact, according to the National Renewable Energy Laboratory, plugged-in equipment such as computers and copy machines can account for as much as 30 percent of the building's total

Getting Up to Speed CONTINUED ON NEXT PAGE

Although v4 has incorporated significant changes, for folks already quite familiar with LEED 2009, this latest version won't be too big of a stretch.

Also, with the USGBC making such an effort to engage the building industry with half a dozen rounds of comments, for those following the cycles, the forum was a great way to learn about where v4 was headed.

In terms of getting up to speed with the actual changes, a good place to start is a complimentary V4 User Guide offered by the U.S. Green Building Council.[3] In addition to describing the underpinnings of v4's philosophical shift, the guide offers an at-a-glance listing of all the changed and new credits.

"At the risk of sounding simplistic, it's all about education on the new set of standards. We recommend attending CEUs and webinars, reading articles, the reference manual and supporting documents," suggests Mark Rossolo, global director of public affairs, UL Environment, Portland.

In addition, the USGBC has released a free "Introduction to V4" two-part webinar.4

The first session, "Key Concepts and Strategies in V4," describes the foundations of v4, explains

energy use. Consequently, any technology or best practice that helps reduce plug loads is sure to gain traction.

Another significant change to v4 is the promotion of Demand Response from a pilot program to a full-fledged credit. To earn this credit, a project must shed at least 10 percent of its estimated peak electricity demand through a DR program. And now that building automation systems and submetering technology as matured to a certain point, there are much fewer technological hurdles to reckon with.

Although DR has become fairly common for industrial and manufacturing facilities to help relieve electrical grid demand during peak hours, it has yet to be widely adopted by commercial buildings in dense urban settings. In addition, the utility company still holds many of the cards in determining whether a particular facility qualifies for its program and whether it's willing to offer any incentives for enrolling.

"In my opinion, it is a credit which needs careful research and study and a mandatory consultation with the respective utility company before pursuing," says Chakraborty.

Although Chakraborty anticipates that enrolling in DR programs will not be without hiccups, particularly in smaller cities, he applauds the new credit and is hopeful that it will drive DR programs.

To better inform specifiers and end-users about DR, the Demand Response Partnership Program between the USGBC and Environmental Defense Fund can be very helpful.[2]

Getting Up to Speed continued from previous page

the most significant improvements and delves into LEED's vision of the integrative process.

In the second webinar, "Performance: Measuring for Success in v4," the presentation demonstrates how metering will be used as a key metric to measure actual building performance, addresses select performance-based credits within each of the six v4 categories and defines newer terminology.

Available for purchase, the USGBC has also furnished two different five-part series on the D+C and the O+M Rating Systems.

Overall, Ronald Collis, AIA, LEED AP, senior associate, KPS Group, Birmingham, Ala., recommends that the quickest way to learn is to jump right in. In addition, he advises, "make use of the resources, interpretations and forum in the Online Credit Library. Folks can also learn from those who participated in the LEED v4 Beta program or have recently begun a v4 project. Most everyone is willing to share their lessons learned."

A Look at Lighting

Clements also explains that the majority of ASHRAE 90.1-2010 energy savings, as compared to 2007, are centered around lighting. In particular, a 17 percent reduction in lighting power density will be required in tandem with increased implementation of lighting controls. Furthermore, bi-level switching—where alternate rows, fixtures or lamps are separately circuited and independently controlled—has also become a new LEED requirement.

"There will have to be more emphasis on building siting, orientation and its effect on lighting systems," says Saad. "Lighting uses a lot of energy and also creates waste heat which drives HVAC sizing and use, so design teams will have to be innovative at communicating the synergistic effects of daylighting—such as reduced heating load and improved indoor environment—whose value is not always readily apparent in value engineering discussions."

Another noted change is an updated daylighting credit prioritizing spatial daylight autonomy (sDA), which reflects advancements in daylighting modeling. Although the more simplistic illuminance calculations for specific points within a year-long cycle can still be applied, designs which utilize sDA will be in a position to receive more points. Defined as the percentage of the work plane that is higher than 300 lux, or 28 footcandles, at least 50 percent of occupied hours, sDA is considered to be a more accurate assessment of quality daylighting. That being said, the metric does have a tendency to encourage overglazing, so to counter this, v4 also requires glare simulations.

In the Light Pollution category, v4 has an updated performance-based option drawing from the International Dark Sky Association's Model Lighting Ordinance in addition to a new Illuminating Engineering Society of North America Backlight, Uplight, and Glare (BUG) rating and calculation method. For v4's new prescriptive option, specifiers can match the BUG ratings for assorted fixtures with the needs of their lighting zone.

Every Drop Counts

Moving on to updated water conservation requirements, Chakraborty relates, "I am particularly impressed with the new water efficiency requirements in LEED v4, especially mandating outdoor water use reduction, whole-building level water metering and sharing the data with USGBC for five years, as well as the inclusion of cooling tower process water savings within the indoor water use prerequisite."

Chakraborty likes the fact that the Cooling Tower credit encourages projects do perform a chemical analysis of the blowdown water and maximize water cycles to the cooling tower. By analyzing and cycling back blowdown water below certain chemical levels, as opposed to immediately draining it from the cooling tower, he says that thousands of gallons of water can be saved.

Expanding way beyond low-flow fixtures, which incidentally will have to be WaterSense labeled, v4 also takes into account process water use from other equipment such as dishwashers, washing machines, commercial kitchen equipment, and laboratory and medical equipment.

By evaluating a project's overall water budget, Lorenz anticipates that this will require more of a more holistic design strategy in place of point chasing.

As with energy, water metering will play a key role as a new prerequisite. "Building occupants and facilities management are rarely connected with the water impacts of their actions and management," says Lorenz. "When the reality is 'what gets measured gets managed,' this prerequisite will arm building users and managers with the information they need to reduce their water use."

Another interesting semantic change is the fact that the term stormwater has been replaced with rainwater. As Schaffner explains in USGBC's webinar, "rainwater is viewed more as a resource, whereas stormwater connotes something dirty that one must get rid of."

Although Baum is encouraged by the water efficiency updates, she is concerned that some of the changes won't be favorable to healthcare facilities. "My primary criticism is that there are five points available for domestic plumbing fixture water reduction in hospitals, but healthcare projects today typically can achieve no more than two to three of those points, based on code requirements and plumbing fixtures available on the market. I would have liked to have seen those extra points be put to something more worthwhile."

Full Disclosure

"The topic that has the entire building materials industry shaken," as Chakraborty describes it, is unprecedented Building Product Disclosure and Optimization credits, essentially requiring building product manufacturers to tell all.

While project teams are very pleased about the prospect of knowing exactly what kinds of substances they are potentially putting into their buildings, manufacturers and suppliers have traditionally been hesitant about furnishing such information.

"The reality in our marketplace that most construction products are not patented or patentable, so most manufacturers live in a world of trade secrets," explains Lucas Hamilton, manager, building science applications, CertainTeed, Philadelphia. "It's hard to open up your books to LEED and trust that they will guard the secrets of where the product comes from, who your suppliers are, how the product is made and how far it had to travel."

Recognizing this quandary, the USGBC made a big effort to work together with the manufacturing community to come up with a mutually agreeable approach to transparency. The answer, says Hamilton, is the idea of using independent, trusted, third-party organizations to perform the product evaluations and report the results in a way that provides the necessary information, while protecting manufacturers' privacy.

Because this new EPD requirement is a ground-breaking move toward driving product disclosure, the USGBC felt it necessary to reward the specification of building products with EPDs, regardless of what those EPDs reveal. In other words, the credit does not judge the actual material and chemical make-up of a building product and therefore, many are concerned that this may spur greenwashing.

Clarifying the credit's intent, USGBC Media Associate Jacob Kriss explains, "the purpose of this is to accelerate the availability of environmental impact data in the market for consumers to use when selecting products."

Kriss also points out that a second option within the EPD credit does award an additional point for specifying products that have a demonstrated an environmental impact below industry average for that particular product type.

Another industry concern has been the lack of standardization amongst the assorted industry standards and tools available for product transparency reporting. To address this, the USGBC recently sponsored a task force to harmonize the different tools and assessment systems, drawing funds from a $3 million Google grant.

"Their work is already helping to sort out the relationships between several organizations in this space whose work is very complimentary," reports Perry. "From where I sit, it looks like the industry is rallying around transparency as an idea whose time has come."

While many in the building products industry are still grumbling about this daunting task, which involves things like assembling detailed product ingredient data, reporting material extraction information and assessing the environmental impacts of all aspects of product manufacturing and transport from cradle to grave, others are encouraging.

"It will be difficult for manufacturers initially, but it is achievable," assures Ronald Collis, AIA, LEED AP, senior associate, KPS Group, Birmingham, Ala. "It wasn't that long ago that reporting VOCs and recycled content was a big deal. In time LCAs and EPDs will become the norm and manufacturers will be using them to market their products. A few already do."

In a similar vein, UL Environment Product Manager Paul Firth asserts that manufacturers have been researching their product life cycle and business supply chains for years, and should have the necessary data on hand to begin an LCA.

One of the initial steps of this process, already underway, is the development of Product Category Rules (PCR) for manufacturers within each building materials industry to adhere to as they develop EPDs. For example, the concrete industry has already gotten a jump start on this with the National Ready Mixed Concrete Association providing third-party validation services for various concrete related products.

Ultimately, Lorenz envisions a sink or swim type of scenario with the companies adapting the most rapidly to meet growing market demand thriving, while those who hesitate will be left behind.

Taking a look at how some manufacturers are handling this new reality, CertainTeed has benefitted from the experience of its parent company, Saint-Gobain, which is headquartered in Europe where EPDs are already much more established, according to Hamilton.

Meanwhile, Construction Specialties (C/S) has been actively working toward product transparency with McDonough Braungart Design Chemistry and an ISO 14001 certifier. Credited as the first building materials company to produce an on-product ingredient label, C/S has also been working with the Cradle-to-Cradle Products Innovation Institute for several years.

"I'm personally happy to see the needle in the materials category moving away from single attributes and toward both environmental and human health," says Curt Fessler, LEED AP BD+C, marketing director, Construction Specialties, Muncy, Penn.

While product disclosure is a strong step in the right direction, Lorenz cautions that time, expense and effort required to develop LCAs and EPDs will likely trickle down to the price of production and require product changes across many companies and suppliers.

Architects and designers should also anticipate getting hit with a flood of information as manufacturers start releasing more detailed product data.

"Much education will be needed for the A&D community to understand the data that will be available to help specifiers not view it out of context," explains Josh Jacobs, manager, UL Environment Technical Information and Public Affairs.

Integrated to Integrative

In promoting a higher level of building team collaboration during a project's early stages, v4 has thoughtfully changed its language from "integrated" to "integrative" with a new integrative process credit.

As Holley Henderson, LEED Fellow, founder of H2 Ecodesign and member of the LEED Steering Committee, explains in the "Key Concepts & Strategies" webinar, that "integrated" implies something has an end, whereas the idea of "integrative" connotes an iterative, ongoing process which continues all the way through to building occupancy.

In a similar vein, as opposed to painfully value engineering things out of a project, v4 prefers the language, "continuous value optimization" to communicate the idea of optimizing the building design in a more positive light.

"This is a much needed change," says Saad. "While IPD increases onsite commitment from multiple disciplines, it also helps reinforce the overall goal and success of the project."

One of the ideas behind the integrative process is soliciting input from folks who actually use the building, not just the owner. In addition to building occupants, facility managers are often an untapped resource and can offer valuable post-occupancy insights to better inform the design and construction process.

However, the key is to bring all the players in early. “By applying the integrative process, it allows teams to make early decisions about the design of the project that affect not only the energy use, but how you site the building, orientation, massing, the envelope, the sun angles, etc,” explains Simon in the USGBC webinar.

Ultimately, it’s all about shifting the way that design teams view building projects from a piece-meal type of approach toward a much more holistic view. It’s a matter of systems thinking and understanding how all the parts and pieces work together, says Schaffner.

Moving Forward

Despite the concerns that v4 is raising the bar too far and too fast, overall, the industry is applauding the USGBC’s bold upgrade of the rating system and commending the organization for its industry leadership.

“Each new version of LEED builds on the lessons learned from previous experience and uses those lessons to inform the next iteration and raise the bar. LEED v4 is no different and is the next step in the evolution of sustainable design,” observes Collis.

“Albeit, there will be some initial frustrations and drawbacks, but with time it will all prove to be worth the effort,” adds Chakroaborty. “We are in for some exciting times ahead.”

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Take the quiz online: http://thececampus.com/ARWFALL14Quiz

Reflective Roofs and Urban Heat Islands

PROTECTING PEOPLE, THE ENVIRONMENT AND THE ECONOMY

By Dr. James L. Hoff, DBA

All images courtesy of Duro-Last

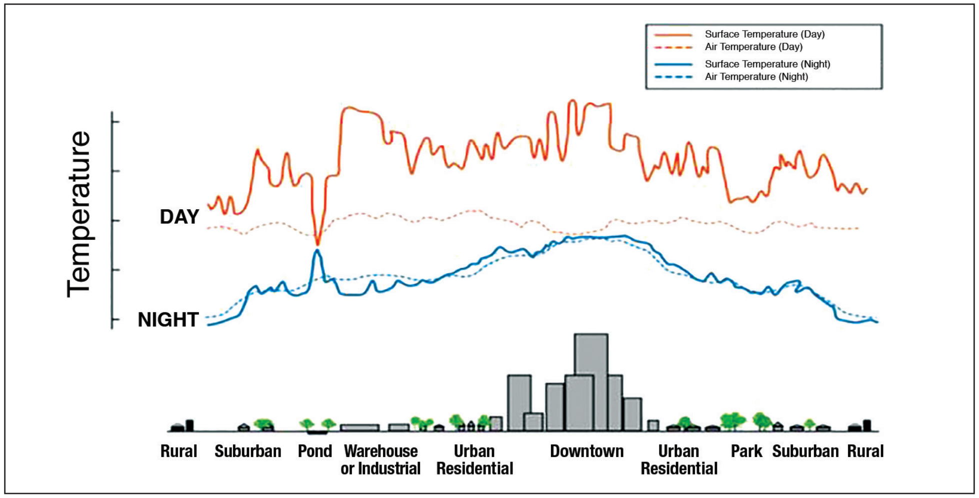
This article provides an overview of the urban heat island effect that impacts almost all major cities across the globe. The article suggests that urban heat islands pose a significant problem, negatively affecting the world economy, environment, public safety and human

Learning Objectives

1. Understand the basic science behind the urban heat effect.
2. Identify the risks and consequences of the urban heat island effect on cities and their residents.
3. Identify the strategies currently available to mitigate the effects of urban heat islands.
4. Review the key criteria for designing and selecting a reflective roofing system to optimize its contribution in mitigating the urban heat island effect.

health. Based on a review of the available strategies to mitigate the negative consequences of the heat island effect, the article also suggests that reflective roofs offer the most feasible and cost-effective way to immediately start improving conditions in urban heat islands. Finally, the article suggests that cool reflective roofs, when designed and installed correctly, may provide many years of useful service while reducing heat island impacts at the same time.

Figure 1: Typical Urban Heat Island Profile (Source: U.S. EPA[3])



What is an Urban Heat Island?

As urban areas across the globe have grown in size and density, significant changes have taken place in their landscape. Buildings, roads, parking lots, and other infrastructure replaced open land and vegetation. Surfaces that once were permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape.

It is important to note that the heat island effect occurs both on the surface and in the atmosphere. By noon on a hot summer day, the sun can heat urban surfaces such as roofs and pavements to temperatures 50 to 90 degrees Fahrenheit hotter than the air. In turn, these surfaces radiate additional heat into the atmosphere, causing a similar but not as extreme increase in air temperature. This atmospheric heating becomes more pronounced after sunset as urban surfaces continue to radiate heat into the surrounding air. According to the U.S. Environmental Protection Agency, the annual mean air temperature of a typical city with one million residents may be 2 to 5 degrees warmer than its surroundings. And on a summer night, this increase in temperature may be as much as 22 degrees Fahrenheit.[2]

A cross-section of a typical urban heat island is illustrated in Figure 1.[3] The illustration shows how urban temperatures typically are lower at the urban-rural border than in dense downtown areas. The illustration also shows how parks, open land, and bodies of water can create cooler areas within a city.

Figure 1 also helps illustrate the critical relationship between surface and air temperatures. Once heated, the hard surfaces of asphalt and concrete typical in urban areas tend to maintain an increased temperature for almost the entire day. And the heat retained and emitted by these hard surfaces during the evening causes the air temperature at night to become almost identical to the temperature of the heated urban surfaces.

However, one critical factor not illustrated in Figure 1 is the ultimate source of urban heating. With the exception of heat from geothermal sources as well as man-made and natural combustion, over 99 percent of the heat in our atmosphere is a result of solar radiation.[4] As a result, almost all temperature effects associated with urban heat islands can be traced to increased absorption of solar radiation by urban surfaces. And as we will discuss later in this article, reducing solar heat absorption is the most critical factor in addressing the problems of urban heat islands.

Why are Heat Islands a Problem?

Elevated temperatures in urban heat islands, especially during the summer, may have numerous negative consequences for the environment and quality of life in urban areas. These adverse consequences may include:

- **Increased peak energy consumption and costs.** Higher urban temperatures in summer increase demand for air conditioning and related electricity consumption. Studies conducted by researchers at Lawrence Berkeley Laboratory estimate that the heat island effect is responsible for 5 to 10 percent of peak electricity demand.[2] In addition, the actual cost for this electricity to the individual building owner may be much higher when peak demand charges are included in the monthly electric bill.[5]
- **Increased risk for brownouts and blackouts.** Increased peak air conditioning demand in urban heat islands poses additional risks beyond higher electric bills. Even without the additional heat load associated with heat islands, peak electrical demand in the summer may run dangerously close to the maximum capacity the electric grid can provide. And when the grid fails to meet peak demand, the results may be devastating. As an example, heat island-driven peak demand is closely related to a number of well-known power failures in the United States, including the state of California in 2000 to 2001 and the city of Chicago in 1995. In all of these cases, peak demand for electricity during prolonged heat waves exceeded the capacity of the electric grid, causing frequent brownouts as well as occasional complete failure of the grid.
- **Increased air pollution.** Increased peak energy demand generally results in greater emissions of pollutants from power plants. And much of this increased pollution may impinge directly on the air in an urban area since the power plants providing peak power frequently are located close to the cities that generate the peak demand. In addition to raising power plant emissions, higher air temperatures also promote the formation of smog, or low-level ozone.
- **Compromised human health and comfort.** Every degree of increased temperature in an urban heat island makes it more and more difficult for a city's population to remain comfortable, productive, and even safe in the event of

natural emergencies, especially events that may shut down the electric grid. Warmer days and nights, along with higher air pollution levels, can contribute to general discomfort, respiratory difficulties, heat cramps, exhaustion, non-fatal heat stroke, and heat-related mortality.

- **Impaired water quality.** Hot pavement and rooftop surfaces transfer their excess heat to storm water, which then drains into storm sewers. This heated storm water then raises water temperatures as it is released into streams, rivers, ponds, and lakes, causing temperature changes that may be stressful to aquatic organisms. Elevated water temperatures also reduce the oxygen capacity of water and its ability to decompose sewage and other pollutants.

What Can We Do About Urban Heat Islands?

Although the urban heat island effect could be addressed simply by removing a city's buildings and pavements and replacing them with open land and vegetation, such a solution would effectively eliminate the urban area itself along with the heat island. As a consequence, the only practical way to address this challenge is to transform these urban surfaces rather than eliminate them. And this transformation must somehow eliminate or reduce the tendency of these surfaces to absorb and retain heat. Without a doubt, pavements and roofs offer the best opportunity to reduce urban heat absorption. When combined, roofs and pavements account for over 60 percent of the entire surface area of modern urban areas, with roofs contributing 20 to 25 percent and pavements contributing 30 to 35 percent.[6]

Because transformation of roofs and pavements appears to be the most effective approach to heat island mitigation, almost all current global strategies are directed toward making the roofs and pavements of cities less heat absorptive. In lieu of this solution, we can plant more trees and create more parks. But given the scarcity and economic value of urban real estate, such a strategy may have only a limited impact on overall urban temperatures. As a result, this article will focus primarily on the various ways we can reduce the heat absorption of roofs and pavements.

It's easy to understand why there is so much public reference to the word "cool," as in cool pavements and cool roofs. If the fundamental problem is related to excessive heat in urban pavements and rooftops, then the obvious solution would be to reduce their temperatures and make them much cooler. Without getting into a complex discussion of thermodynamics, there are a number of ways to make hot surfaces cool, and a brief review of these different approaches should be helpful.

Shading

Hot urban surfaces may be cooled through the use of shading, or blocking the sun's radiation before it is absorbed by the surface. Common examples of this strategy include the planting of trees to provide shade as well as the installation of awnings or solar shades to block sunlight from hitting highly absorptive surfaces. Although shading may be a useful strategy for small heat reductions in highly targeted areas such as sidewalks and patios, it is difficult to envision large-scale applications that would address more than a small percentage of current urban area.

Evaporation/Transpiration

The temperature of urban surfaces also may be reduced by evaporation, or the heat transfer achieved when water moves from a liquid to a gaseous state. As an example, water fountains can be very effective in cooling nearby surfaces as well as the surrounding air. Unfortunately, just like shading strategies, the overall reduction in urban heating achieved through evaporation may be relatively small. In addition to the direct evaporation of a water fountain, it should be noted that a portion of heat reduction attributed to trees and other plants involves a form of evaporation called transpiration. During transpiration, plants give off water vapor in order to cool their leaves and facilitate the movement of nutrients. The most obvious applications of transpiration to reduce surface temperatures in urban areas would include any garden or park area where pavements have been replaced by extensive plant cultivation. But just like shading strategies, the amount of urban area that may be dedicated to, or suitable for, gardens and parks likely is limited.

One final application of transpiration in urban areas involves the installation of "green" roofs consisting of a variety of plants that may be installed in a depth of planting media directly over new or existing roof surfaces. Many cities across the globe have adopted programs to encourage the installation of green roofs, but the cost of a vegetated roof may be difficult to justify for the sole benefit of surface cooling. As a result, green roofs tend to comprise a very small proportion of urban roof installations. For instance, a survey of green roof installations estimated that slightly over 20 million square-feet of green roofs were installed in North America in 2013.[7] Although 20 million square-feet may appear to be a sizeable number, it accounts for less than 1 percent of the 3 billion square-feet of low-slope non-residential roofs installed annually in North America.[8] Therefore, the potential for green roofs to make a significant impact on heat islands appears to be almost as limited as previously discussed shading strategies.

Advection

The temperature of urban surfaces also can be reduced through advection, or the effects of wind blowing across a heated surface and cooling it. As an example, a 2005 modeling study of rooftops in downtown Chicago suggested that roof surface temperature may be reduced by the effects of wind.[9] However, other studies using larger "urban canyon" models suggest that the effect of wind on urban surfaces is very complicated and in many cases can actually lead to increased heat absorption.[10] Regardless, it should be obvious that whatever benefits attributed to wind would be highly unpredictable and probably not useful as a heat island strategy.

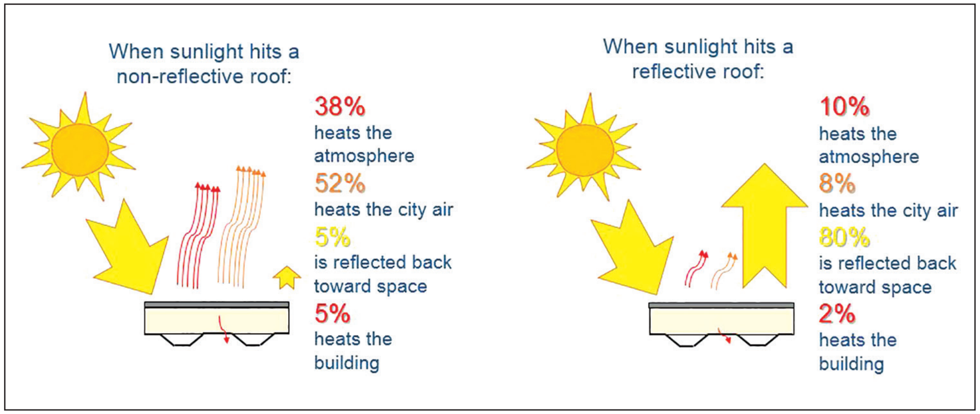
Reflection

Finally, the temperature of urban surfaces can be reduced through reflection, or the redirection of solar energy away from urban surfaces and the heat island itself. Although both roof and pavement surfaces can be made to be reflective, cost-effective technology suitable for immediate and scalable application is only available at this time for reflective roofs. Given the urgency of reducing heat island effects, it is likely that new reflective paving products will become commercialized in time; but for today's cities, reflective roofing offers the best immediate answer to reducing heat island effects.

Because reflective roofs offer the primary technology available today to address heat islands, it is important not to underestimate their potential contribution. As previously stated, roofs account for approximately one-quarter of urban surface area; and if reflective roof technology can be used to significantly reduce heat absorption over such a sizeable surface area, its potential contribution would be substantial.

In order to better understand the potential contribution of reflective roof technology, it may be useful to evaluate how a typical reflective roof compares with a traditional non-reflective roof in removing solar heat from urban areas. Figure 2 provides such a comparison based on data developed by the Heat Island Group of Lawrence Berkeley National Laboratory and published by the Global Cool Cities Alliance.[11]

Figure 2: Reflective versus Non-reflective Roof: Where Does the Heat Go? (Source: Global Cities Cool Roofs and Cool Pavements Tool Kit[11])



As shown in Figure 2, when sunlight strikes a traditional non-reflective roof surface, only 5 percent of the total heat energy is effectively removed from the urban heat island by reflection back toward space. Instead, 52 percent of the energy heats the air directly around the urban area, 38 percent heats the larger atmosphere above the heat island, and 5 percent heats the building or area directly beneath the roof. However, when sunlight strikes a reflective roof, up to 80 percent of the total heat energy is reflected back toward space, leaving only 8 percent of the energy to heat the city air, 10 percent to heat the atmosphere above the city, and 2 percent to heat the building. As a result, the reflective roof may effectively remove up to 80 percent of the heat energy that otherwise would impact the heat island. Assuming that roofs account for 25 percent of the urban area, the overall potential decrease in solar heat absorption would be 80 percent times 25 percent, or a 20 percent total reduction.* That's pretty impressive for a single technology available for immediate and full-scale deployment today.

Benefits of Reflective Roofs

For cities and their inhabitants. Just as elevated temperatures in urban heat islands pose numerous negative consequences, reflective roofs offer an equally long list of potential benefits to improve the environment and quality of life in urban areas. Important benefits of reflective roofs for cities and their inhabitants include:

- **Lower heat island temperatures.** Simulations run for several cities in the United States suggest that citywide installations of highly reflective roofs and pavements, along with planting shade trees will, on average, reduce ambient air temperatures by 4 to 9 degrees Fahrenheit in summer months.[12]
- **Reduced peak energy demand.** By reducing air temperatures and the associated demand for air conditioning at critical peak periods during the day, the installation of reflective roofs and surfaces may reduce overall peak electricity demand in urban areas by as much as 5 to 10 percent.[2]
- **Lower air pollution.** The combination of lower overall temperature and reduced peak demand offered by

reflective roofs and surfaces may lead to reduced air pollution by lowering the amount of power plant emissions and by reducing the temperature-related formation of smog, or low-level ozone.

- **Reduced risks from blackouts.** By lowering peak electricity demand, reflective roofs may reduce the risk of power blackouts. And in the event a blackout does occur, reflective roofs continue to divert solar heat away from buildings and help occupants stay cool without the use of air conditioning.
- **Improved quality of life.** Reductions in overall air temperature and urban air pollution combine to provide a healthier and a safer environment for a city's inhabitants, leading to improvements in work productivity and leisure activity.

For Building Owners

Perhaps the most noteworthy aspect of reflective roofs is that so many of their benefits accrue directly to the building owners who invest in them. Important benefits of reflective roofs for building owners include:

- **Lower electric bills.** Because many electric utilities, especially in urban areas, add peak demand charges to their electric bills, the dollar savings available from installing a reflective roof may be many times more than the actual reduction in peak usage. For example, a recent study of peak electric charges suggests that the costs associated with peak electricity demand charges may account for over 50 percent of some electric bills during the summer. In addition, this study suggests that the annual savings available from a reflective roof installed on an existing 20,000-square-foot commercial building may vary between $880 and $3,040, depending on utility rates and climate zone.[5]
- **Reduced equipment sizing/improved service life.** Because air conditioning equipment must be sized to accommodate peak cooling loads, reflective roofs may help lower the overall size of the compressors and air handlers needed to cool a building. And because reflective roofs may lower roof surface temperatures by as much as 50 to 60 degrees Fahrenheit, rooftop air conditioning units will operate at reduced temperature differentials, which may extend the service life of equipment.
- **Competitive cost.** In many cases, a reflective roof may cost no more than non-reflective roofing options. Table A provides a comparison of reflective surface cost premiums for the most popular commercial roofing materials, as estimated by the U.S. Department of Energy (DOE).[13]

In addition to the DOE estimates shown in Table A, the cost effectiveness of reflective roofs may be demonstrated by the significant increase in market share they have achieved in the past 10 to 15 years. From less than 20

Table A. Cost Premiums for Commercial Reflective Roofing Options
(Dollars per Square Foot)

Roofing Material	Traditional Surface Options	Reflective Surface Options	Cost Premium
Asphalt Built-Up Roofing (BUR)	Crushed stone	Reflective aggregate (e.g. marble chips)	\$0.00 – \$0.20
Modified Bitumen	Mineral cap sheet	White or other reflective mineral cap	\$0.50
Thermoplastic (PVS, TPO)	White or colored surface	White or other reflective surface	\$0.00
Thermoset (EPDM)	Dark surface	White or other reflective surface	\$0.10 – \$0.50
Spray Polyurethane Foam (SPF)	Field-applied coating	White field-applied coating	\$0.00
Architectural Metal Roofing	Factory-applied coating	White or other reflective coating	\$0.00

Source: U. S. Department of Energy[13]

percent of the low-slope commercial roofing market in 2000, reflective roofs have grown to around 50 percent of the market ten years later in 2010 and probably well over 50 percent today.[8]

- **High return on investment.** Because there is little or no cost premium associated with reflective roofs, the return on investment may be very high, especially for new buildings or existing buildings requiring a new roof simply due to age or other reasons. So when a building owner selects any of the roofing options shown in Table A that require no cost premium, all of the dollar savings from reduced electricity bills drop directly to the bottom line.

Selecting a Reflective Roof: Important Considerations

Although a suitable reflective roof may be available for almost any commercial roofing need, a number of additional considerations should be examined before selecting the best reflective roofing system for any particular application.

Reflective roofing standards. As a starting point, the roofing option selected should meet or exceed the best current codes and standards for reflective roofing in order to maximize long-term benefit and performance. For roofing products to be considered reflective by today's standards, the product must be tested to achieve a minimum Solar Reflectance Index (SRI) rating. This index combines two measures critical to evaluating the total reflective potential of a roofing product. The first measure is Solar Reflectance (SR), which quantifies the amount of solar energy that is directly reflected by the material. The second measure is Thermal Emittance (TE), which quantifies the amount of solar energy that is indirectly released to the atmosphere or adjacent spaces after the material is heated by the sun. Looking back at Figure 2, the solid arrows represent the SR portion of solar energy that is directly reflected, while

Table B. Current Reflective Roof Standards
(Low-Slope Roofing Applications)

Building Code / Energy Standard	Min. Solar Reflectance Index (SRI) Initial	Min. Solar Reflectance Index (SRI) 3-Year Aged
International Energy Conservation Code (2012-2015	82	64
ASHRAE 90.1 Energy Standard (2013)	n/a	64
California Title 24 Energy Standard (2013)	n/a	75

the wavy arrows represent the TE portion of energy that is indirectly emitted after the material has been heated.

In order to evaluate the total amount of energy removed by a reflective roof, it is necessary to combine the SR and TE of the material into a single SRI index. Almost all national energy codes and standards now use SRI as the reference standard for roof reflectance, and many of these codes and standards have established minimum SRI levels, both initial and after aging for 3 years. Table B provides a brief summary of both initial and aged minimum SRI values for three of the most-recognized U.S. building codes and standards—the International Energy Conservation Code, the ASHRAE 90.1 building energy standard, and the State of California Title 24 energy standard.

The building owner and designer should use the SRI range in this table as a guideline for product selection. To help verify that a product selected meets or exceeds the relevant SRI value, most roof system manufacturers identify the SRI of their products on published product information sheets and other technical literature. In addition, a free online listing of the tested and certified SRI of hundreds of roofing products is maintained by the Cool Roof Rating Council, which also maintains the building code-recognized standard for testing and reporting SRI. Additional information about the Cool Roof Rating Council is included in the "For More Information" section of this article.

Reflective roofs and aging. As shown in Table B, reflectivity values for roofing products are measured both initially and after an aging period. This is because the reflectivity of a roof surface tends to degrade due to aging of pigments and discoloration caused by surface accumulation of dirt, airborne pollutants, and biological growth. Although some roofing researchers originally suspected that the decrease in reflectivity over time might be significant, field studies conducted on a wide variety of reflective roofing types suggest that roof reflectivity tends to stabilize over time and probably never falls much below an SRI of 50 under typical field conditions.[14]

Because most reflective roofing systems maintain a relatively high level of reflectivity over time, it is likely that any attempts to wash or clean the surface of the roof will not offer any significant economic benefit. In fact, many roofing professionals do not favor the cleaning of roofing surfaces because the cleaning process may accelerate the overall aging of the system and reduce service life.[14]

Finally, it is important in any discussion of roof aging to draw a distinction between installing a high-performance commercial roofing system and merely painting an existing roof. In general, most commercial-grade roofing systems are available with in-service performance warranties that may extend for up to 20 years or more. In the case of paint or a commodity roof coating obtained from a local building supply, however, the available warranty may be non-existent or less than a few years. Although warranty terms and conditions may vary widely from product-to-product, it is important that the building owner or designer carefully verify the type and extent of warranty coverage that is available for the roofing system or product selected.

Comparing reflective roofing options. Because reflective roofs are available in all major technologies, the selection of the best reflective roof for any application may be made based on economics and performance. Perhaps the best approach is to combine economics and performance by looking at the long-term life cycle cost of the roofing system. Such an approach may be especially useful if there are periodic maintenance requirements for one type of reflective roofing system as compared to another. As an example, if a reflective roof coating system requires recoating every so many years, it may have a higher long-term life cycle cost than a reflective single-ply system that requires minimal maintenance over its service life.

Reflective roofs and roof insulation. After finalizing a decision to install a new reflective roofing system, it is important not to neglect the underlying thermal insulation. In terms of return on investment, the best time to increase insulation levels is at the time a new roof is installed, especially when reroofing over an existing roof. As a general guide for roof insulation levels, the same major codes and

Table C. Minimum Above-Deck Roof R-Values
(Source: 2015 International Energy Conservation Code / ASHRAE 90.1-2013)

Climate Zone[a]	Example U. S. City	Min. Roof R-Value[b]
1	Miami, FL	20
2	Houston, TX; Phoenix, AZ	25
3	Atlanta, GA; Dallas TX	25
4	Baltimore, MD; St. Louis, MO	30
5	Chicago, IL; Pittsburgh, PA	30
6	Milwaukee WI; Minneapolis, MN	30
7 & 8	Duluth, MN	35

a. Per ASHRAE 90.1-2013 climate map
b. Roofs with insulation entirely above deck

energy standards mentioned previously may serve as the best references. In these codes, the thermal performance of roof insulation is measured by R-value; and in general, all of these codes and standards recommend R-value levels from between R-20 to R-35 for typical commercial roofs with insulation above the roof deck. Table C provides a summary by climate zone of minimum above-deck R-value levels in the most recent editions of the International Energy Conservation Code and the ASHRAE 90.1 building energy standard.

In addition to designing for at least the minimum amount of roof insulation required by code, it is also important to install the insulation in two layers with staggered joints, in order to limit air infiltration and thermal loss.

Reflective roofs and adjacent surfaces. Some building researchers have reported incidents when the heat and light reflected from a reflective roof may impinge on nearby surfaces such as walls and windows. In some cases, the increased heat on adjacent surfaces appeared to accelerate the aging of the surface; in other cases the reflected light caused an observation of glare through nearby windows.[15] Although the reports to date appear to be limited in scope and anecdotal, it may be prudent for the building or roofing designers to consider the potential for heat and light reflection on adjacent structures during the design stage of any project involving a reflective roof.

Reflective roofs and moisture movement. Some building researchers also have reported incidents where moisture may have condensed and accumulated within reflective roofing systems, mostly in very cold climates. Similar to reports of the effects of reflective roofs on adjacent surfaces, many of the reports of roof condensation are anecdotal and appear to frequently be associated with other roof design or quality issues.[15] For additional information, a recent paper reviewing the issue of roof condensation in reflective roofs is included in the "For More Information" section of this article.

Installing a Reflective Roof: How to Maximize the Benefits

After selecting the best reflective roof for any application, it is also important to maximize the benefits of the roof by minimizing the potential for degradation of the reflective surface finish. In order to achieve an optimal level of reflectivity over the service life of the roof, several strategies should be employed, both during installation and over the service life of the roof.

During installation. The key to maximizing long-term reflectivity during installation involves minimizing the effects of roof traffic. All roofing crew members should wear clean, non-marring shoes, and all construction debris should be removed promptly. Because each and every installation activity may increase the potential for surface degradation, the building designer or installer should consider the use of a pre-assembled roofing membrane that reduces both the time required for installation and the potential to mar the surface during installation.

During use. Just as during installation, the key to maximizing long-term reflectivity during use also involves limiting the effects of roof traffic. To accomplish this, access to the roof should be controlled and limited only to qualified maintenance personnel. And just like the original roofing crew, all maintenance personnel should wear clean, non-marring shoes. Finally, the roof surface should be inspected after storms for damage, and all roof drains should be maintained free of debris that could allow water to accumulate and discolor the roof surface.

For More Information

For the building owner or designer looking to install a reflective roof in the near future, this article should serve as a useful starting point. However, additional information providing a more in-depth look at the issues raised in this article also may be useful. The following documents, all freely available via the internet, are recommended for an expanded understanding of heat islands and the benefits of reflective roofing:

- **EPA Heat Island Home** (http://www.epa.gov/heatisland/index.htm). The U.S. Environmental Protection Agency offers a comprehensive overview of the dynamics of urban heat islands and the role that reflective roofs can play in mitigating their effects.
- **LBL Heat Island Group** (https://heatisland.lbl.gov/). Much of the research work conducted on heat islands by Lawrence Berkeley National Laboratory is available at this site.
- **Global Cool Cities Alliance** (http://www.globalcoolcities.org/). The Global Cool Cities Alliance (GCCA) was launched in 2010 to accelerate a worldwide transition to cooler, healthier cities. Its website offers extensive information about urban heat islands and how cool roofs and cool pavements can help. Especially useful is the GCCA's Cool Roof and Cool Pavement Tool Kit (http://www.coolrooftoolkit.org/read-the-guide/).
- **Recent Articles.** Several articles recently published in *Architectural Roofing & Waterproofing/WC Architect* are referenced in this article and provide important information about some of the key issues and opportunities associated with reflective roofs
- **"Reducing Peak Energy Demand: A Hidden Benefit of Cool Roofs."** This article, published in the Spring 2015 edition, provides a detailed review of the peak demand charges currently applied to commercial utility bills and how the use of reflective roofs can reduce these costs. http://www.arwarchitect.com/articles/85002-reducing-peak-electrical-demand-hidden-benefit-of-cool-roofs
- **"Roofs and Condensation: A Practical Approach for the Design Professional."** This article, published in the Summer 2015 edition, provides a comprehensive review of the issue of condensation and reflective roofs and offers detailed recommendations for the building designer to avoid the potential for roof condensation in the design and installation of any roofing system. http://www.arwarchitect.com/articles/85187-roofs-and-condensation.

Footnotes

Because cool roofs tend to lose some level of reflectivity as they age, the overall energy savings would likely be less than the percentage calculation shown.

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Roofs and Condensation

A PRACTICAL APPROACH FOR THE DESIGN PROFESSIONAL

By Dr. James L. Hoff, DBA

The steady growth of modern single-ply roofing systems over the past 40 years generated many questions regarding long-term performance. Early in their development, many of the questions were related to the capability of single-ply roofing systems to resist external forces such as wind, fire, ultraviolet radiation, and precipitation in all forms. However, with the advent of "cool" single-ply roofs featuring heat reflective exterior surfaces, new questions have emerged concerning the internal forces at play within the roofing system, especially in regard to vapor movement and the potential for moisture condensation within the roof.

Starting with a brief discussion of the fundamentals of vapor movement in roofing systems, this article reviews current research to gain an understanding of the actual incidence of moisture condensation and the key factors that may lead to the accumulation of moisture within single-ply roofing systems. Based on a review of recent experiments and field studies, the paper concludes that moisture condensation in all roofs is a relatively rare phenomenon that tends to occur only in the presence of one or more severe design conditions. These conditions include:

1. Extremely cold external temperatures.
2. Extremely high internal temperatures and humidity.
3. Unusually low amounts of over-deck roof insulation.
4. Unusually high levels of air movement within the roofing system.

Learning Objectives

1. **Understand the basic principles behind vapor movement in roofing systems.**
2. **Identify the key factors that may lead to moisture accumulation in roofing systems.**
3. **Learn how to use available design tools to evaluate moisture movement in roofing systems.**
4. **Identify design strategies to reduce the potential for moisture accumulation in roofing systems.**

The paper also provides a brief discussion of commonly available tools to analyze moisture in roofs, as well as the effect of air barriers and vapor retarders on moisture condensation. In regard to current moisture analysis tools, the paper suggests that these tools may overestimate the potential for moisture condensation in roofs due to the complexity and uncertainty of the variables required. In regard to vapor retarders, the paper suggests that their use involves a number of risks, including the potential for trapped moisture due to external roof leaks as well as reduced air movement within the roofing system to allow drying of the roof over time, commonly referred to as the "self-drying roof" concept.

Based on the review of moisture movement in roofing systems and the tools available to assess and mitigate roof condensation, the paper also provides suggestions for the roofing design professional to deal effectively with moisture movement. These suggestions include:

1. Establish a conservative but realistic estimate for actual interior humidity conditions within the building.
2. Limit unnecessary air movement within the roofing system — both in the design of the roof and in the quality of roof installation.
3. Include a minimum amount of above-deck thermal insulation beneath the roofing membrane.
4. Allow whenever possible the capability of the roof to "self-dry" in the event condensation does occur.
5. Select roofing materials with low perm ratings and high resistance to moisture damage.
6. Use modeling tools, but recognize their limitations.

Introduction

Over the past 40 years, a dramatic transformation has occurred within the commercial roofing industry. From the beginnings of modern commercial construction methods until the last quarter of the 20th century, commercial rooftops were dominated by a single roofing technology: built-up roofing frequently referred to as "tar and gravel" roofs. Beginning in the 1970s, however, a variety of new single-ply roofing technologies emerged to challenge traditional built-up roofing practice. These single-ply systems experienced strong and continuous growth, and by the end of the 20th century, they dominated commercial roofing to the same extent previously enjoyed by built-up roofing.

Compared to built-up roofs, single-ply roofs offered a number of advantages. Single-ply roofs generally require less field labor to install, and the labor conditions themselves are less demanding. Single-ply roofs also tend to be more accommodating to the higher levels of thermal insulation required by today's energy codes, and their lower overall weight allows for economies in the structural design of the underlying roof deck. Due to these and other advantages, single-ply roofs now account for over three-quarters of the commercial roofing market (Tegnos Research, 2012).

As with any significant change in construction practice, the move to single-ply roofing generated questions regarding long-term performance. Early in the development of single-plies, most of these questions were related to the capability of these new roofing systems to resist external forces such as wind, fire, ultraviolet, and precipitation in all forms. As a result of these and other concerns, single-ply roofing manufacturers made significant investments in product development and testing, which have produced achievements in wind, fire, and weathering performance.

Recently, new questions have been raised regarding the ability of single-ply roofs to resist internal forces within the roofing system, especially air and vapor movement. Some of these questions are related to the use of mechanical attachment of single-ply membranes, which may allow additional air movement within the roof. Other questions are related to the increasing use of "cool," or highly reflective single-ply membranes in regard to the potential for vapor condensation beneath such membranes and within the roofing system.

In response to these concerns, this paper provides a review of current research in order to understand the actual incidence of moisture condensation in single-ply roofs and to identify the key factors that may lead to the accumulation of moisture within these roofing systems. The paper also discusses the role of related technologies, such as air barriers and vapor retarders, to control moisture condensation in single-ply roofs. Finally, the paper discusses the role of available building physics modeling tools to help the roofing professional avoid the potential for condensation in roof systems.

Roofs and Moisture: Key Principles

Before reviewing the research evidence about moisture condensation in roofs, it is important to discuss the complex interplay between roofs and moisture. Such a review can be complicated, especially in terms of the underlying factors; but much of this complexity may be summarized in a few key principles to help guide design decisions.

The science is simple, but the factors are complex.

The basic science of condensation is straightforward and well-established. Moisture in the form of water vapor tends to move from a warm, humid condition to a cold, dry condition as the result of the process of diffusion. Due to diffusion, water vapor tends to move from a warm, humid interior of a building to a colder, less humid external environment. This inside-to-outside water vapor movement is typical for buildings during the winter months, especially in the colder regions of North America. Conversely, in the summer in many North American

Figure 1: Winter and summer roof vapor drive

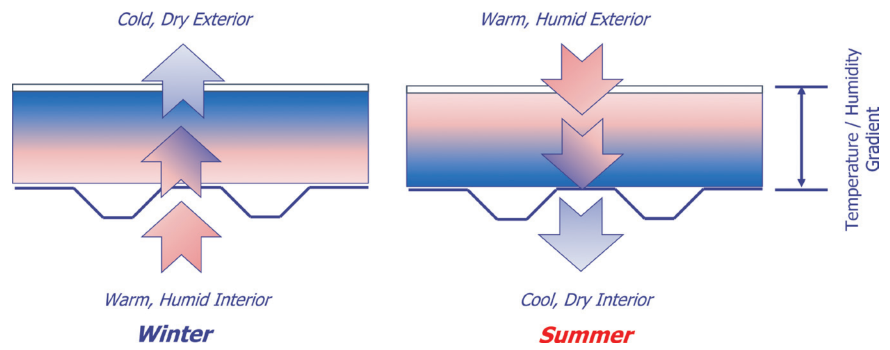
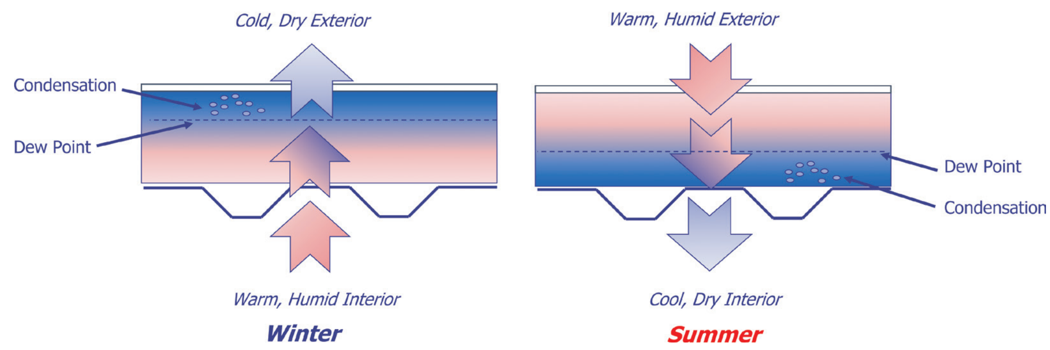


Figure 2: Winter and summer roof dew point condition



climates, this vapor movement via diffusion is reversed, with water vapor moving from a warm, humid exterior to a cooler and less humid interior. Figure 1 illustrates this typical winter and summer diffusion of water vapor within a roofing system.

It should be noted that the movement of water vapor occurs along a relatively predictable temperature/humidity gradient, with the warmest temperature and highest humidity located close to the interior and the coldest temperature and lowest humidity located close to the exterior in the winter. If at any point along this gradient, the temperature falls below the "dew point" for the associated humidity, the water vapor will condense and become liquid water within the roofing system. Figure 2 illustrates this typical dew point condition and the resultant condensation within a roofing system.

Even though this dew point condition may be reached occasionally during the summer in the southernmost climates in North America, the occurrence of condensation in roofing systems is more commonly observed during the winter in the northernmost climates (Griffin & Fricklas, Chap. 6). As a consequence, the findings and recommendations of this article are focused primarily on the potential for roof condensation to occur during the winter heating season, especially in colder climate regions.

Although a theoretical dew point may be calculated based on simple measures of temperature and humidity within a roofing system, there are several important factors that help determine the exact conditions for condensation and the extent that such condensation occurs. First, the rate of vapor drive is affected by the indoor humidity of the entire building (See Figure 1), which may vary widely depending on type of occupancy and function. While large retail and wholesale storage facilities may rarely exceed 30 to 40 percent relative humidity (RH) in the winter, other occupancies, such as heavy manufacturing and indoor swimming pools, may approach 75 to 90 percent RH (See Griffin & Fricklas, 2006, Table 6.4.). As a result, occupancy tends to play a much more important factor in predicting the potential for condensation than either the indoor or outdoor temperature.

Next, the rate of vapor drive is affected by the permeability of the materials within a roofing system, as measured by their perm rating. As defined by current industry standards (ASTM E-96), the higher the perm rating number, the more readily water vapor (in the gaseous state) can be absorbed and move through the material. Table 1 provides a listing of common roofing materials and compares their perm ratings.

For materials with perm ratings less than 0.1, very little if any vapor can be absorbed or transferred. As shown in Table 1, almost all roofing membranes as well as plastic films such as polyethylene are considered to be impermeable to water vapor. For materials with slightly higher perm ratings between 0.1 and 1.0, the rate of vapor absorption and transfer is significantly reduced, especially if the temperature/humidity gradient is not severe. Examples of semi-impermeable roofing materials include individual layers of roofing felt and foam insulations such as extruded polystyrene and polyisocyanurate. For materials with perm ratings above 1.0, the rate of vapor absorption and transfer begins to increase, and such materials tend to absorb relatively large quantities of water whenever they are subjected to temperature/humidity conditions below the dew point. Examples of common semi-permeable and permeable roofing materials include wood and mineral fiber boards, as well as many gypsum products.

Table 1: Perm ratings of common roofing materials.
(Source: Griffin & Fricklas (2006) Table 6.2)

Code / Standard	Code / Standard	Code / Standard
Built-Up Roofing Membrane	0.00 – 0.02	Impermeable (Vapor Proof) < 0.1 Perm
Single-Ply Membrane	0.03 – 0.06	
Polyethylene Film	0.06 – 0.08	
Asphalt Felt	0.3 – 0.8	Semi-Impermeable > 0.1 Perm < 1.0 Perm
Polyiso Roof Insulation	1.0	
Extruded Polystyrene	1.0	
Expanded Polystyrene	1.2	Semi-Permeable > 1.0 Perm < 10.0 Perm
Wood Fiber	3.0 – 5.0	
Gypsum Board	30.0 – 50.0	Permeable > 10.0 Perm

In addition to the rate at which water vapor may transfer through a material, the effect of that transfer on the physical integrity of the material may vary significantly. Under some conditions, materials that may absorb moisture to some degree may be suitable for direct exposure to dew point conditions because the condensing moisture has little or no affect on the integrity of the material. One of the best examples of a less-than fully impermeable roofing product intentionally exposed to dew point conditions is the use of extruded polystyrene in inverted roof systems, where the foam insulation is directly exposed to both rain and condensation. Other foam insulations like polyisocyanurate also have low perm ratings, but the use of facers that can be distorted by moisture makes such materials less resistant to overall condensation and other effects.

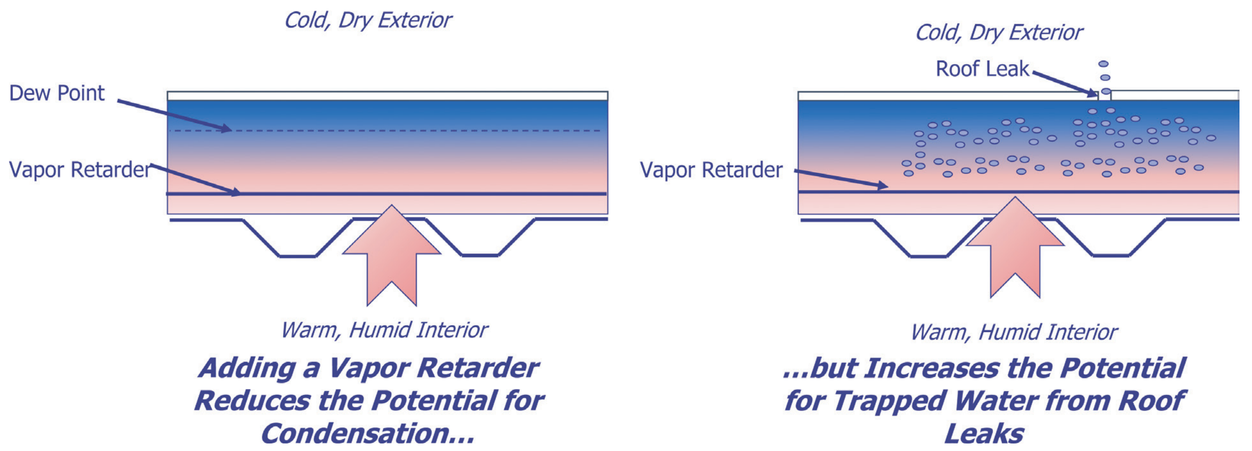
At the opposite end of the perm spectrum, products with relatively high perm ratings tend to absorb significant quantities of moisture. And frequently, this high level of moisture absorption is associated with significant loss of material integrity. As a result, some common semipermeable and impermeable roofing products such as wood and mineral fiber will effectively be ruined when exposed to prolonged moisture condensation.

So far we have only discussed the movement of water vapor due to diffusion, but there is one additional and very important physical force that drives moisture movement. That force is the movement of air itself within a roofing assembly. And the effect of air movement on moisture transfer can be very significant. In a recent study of the effects of air movement versus diffusion (Lstiburek, 2004) the researcher demonstrated that air movement through a small inch square hole in a 4-foot by 8-foot gypsum board panel may drive almost 100 times as much water vapor than would move through the same panel due to diffusion. Although the effects of air movement in this study were related to wall assemblies, the finding of a relatively high level of vapor movement via a relatively small discontinuity in the wall assembly suggest that similar conditions in roofing systems may trigger similar high levels of moisture movement.

Roof Condensation and Roof Leakage Look the Same

The observation of liquid water within a roofing system does not necessarily indicate that vapor condensation has occurred. Moisture may also enter the roofing system via leakage through cuts, punctures, loose seams, and many other discontinuities in the exterior waterproofing layer of the roof. And because roof leakage continues to be a widely reported phenomenon sufficient to fund thousands of roof service operations across the country, excessive moisture in a roof may be attributed more frequently to exterior leakage rather than interior condensation. In fact, several of the research papers reviewed further in this article include observations of roof

Figure 3: Benefits and limitations of a vapor retarder



leaks that may better explain the presence of moisture for some observations of what initially may have been classified as condensation.

Vapor Retarders Help, but There are Unintended Consequences

Installing an impermeable material as a vapor retarder beneath the dew point in a roof certainly will address many of our concerns regarding condensation, but the protection of a vapor retarder comes at a price. If a roof with a vapor retarder experiences roof leaks, the water entering the roof will be trapped above the vapor retarder within the roofing system. However, because the vapor retarder will prevent the water from entering the building, the leak may be unobserved and left unattended for a considerable time. And during that time, the trapped water may spread for a considerable distance from the point of the leak, making it even more difficult to pinpoint the source of the leak and cause extensive damage to a constantly growing portion of the roof. Figure 3 illustrates how a vapor retarder can reduce the potential for vapor condensation but also increase the potential for trapped water due to roof leaks.

Many Roofs Will "Self-Dry" If We Let Them

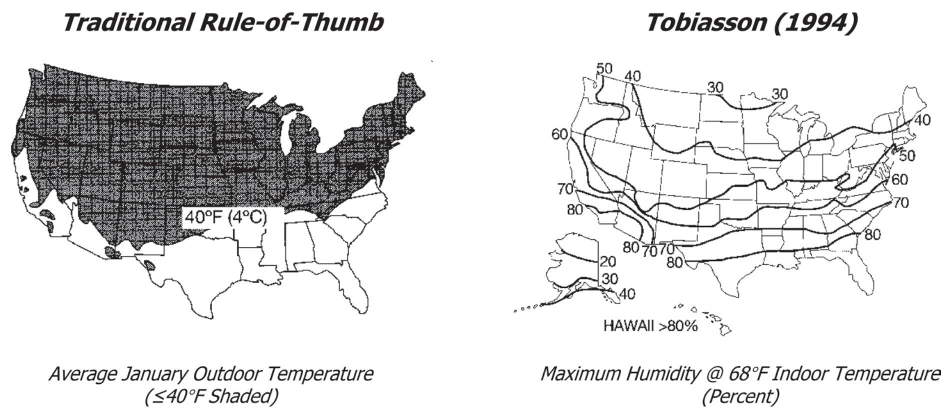
The self-drying roof concept may be traced to field accounts of roof systems observed to have been wet in the winter but dry by the following summer. This condition of wetting in the winter and drying in the summer has now been documented in numerous research studies (see Desjarlais et al., 1998, and Griffin & Fricklas, 2006, Chap. 6). And a considerable body of knowledge has been developed to understand how the phenomenon operates. Self-drying roof systems use the sun and summer heat to evaporate moisture that may have accumulated in a roof due to condensation over the winter. The external heating of the roof reverses the vapor drive and transfers the condensed moisture back into the building where it originated.

The self-drying roof is not only an accidental discovery but also a sometimes-overlooked benefit for the roofing industry. Although under some conditions roofs may experience moisture condensation in the winter, the dynamics of summer heat and sun help to mitigate any potential long-term damage from this winter condensation. However, the self-drying process may only be effective for roofs installed over vapor-permeable decks such as metal or wood and only if a vapor retarder has not been installed as part of the roofing system.

Predicting Roof Condensation: From Rules of Thumb to Computer Models

Due to the effects of the perm rating of materials, the potential for condensation-related damage, and the inadvertent movement of air within a roofing system, the initial scientific simplicity of diffusion-driven vapor movement becomes significantly more complicated—and risky. And the adverse implications of underestimating the potential for condensation within roofing systems may influence roofing professionals to take a conservative approach when assessing the impact of these additional factors. At the same time, addressing the risks of condensation by installing a vapor retarder may result in increased damage from roof leaks and eliminate the self-drying potential of the roof. Because of these risks and consequences, building researchers and roofing professionals have expended

Figure 4: Simplified approaches for recommending a roof vapor retarder. (Source: Oak Ridge National Laboratories)



considerable effort to develop useful tools to aid in the analysis of condensation in roofs and select the best designs to address the effects of condensation.

One of the earliest approaches to roof condensation was a simple rule-of-thumb: if the roof is located in a climate with an average January temperature of 40 degrees Fahrenheit or less, condensation should be assumed and a vapor retarder should be installed. A more sophisticated approach was developed by Tobiasson (1994) who identified the minimum average January temperature that would require a vapor retarder based on the interior humidity of a building. Figure 4 provides two U.S. maps to illustrate these two approaches. The map on the left illustrates the geographic extent of the traditional 40 degrees Fahrenheit rule-of-thumb, while the map on the right illustrates the maximum interior humidity allowed before a vapor retarder is recommended.

As illustrated by the two maps in Figure 4, the 40 degree Fahrenheit January temperature cut-off is more conservative than Tobiasson's indoor humidity approach. As an example, the 40 degrees Fahrenheit map locates Cincinnati, Ohio, within the area requiring a roof vapor retarder. However, the indoor humidity approach would recommend a roof vapor retarder only if the indoor humidity in January exceeds 50 percent RH for a roof in Cincinnati. This is an important difference because many building occupancies, from residences to stores and warehouses, will rarely develop an average humidity above 50 percent in the winter.

Recently a more sophisticated approach to predicting roof condensation has been developed. This approach is called WUFI and was the result of a cooperative effort between cooperation with Fraunhofer Institute for Building Physics in Germany and Oak Ridge National Laboratory in the United States. WUFI is a free software program available from ORNL[1], which allows modeling of heat and moisture over time in complex roofs and wall assemblies. WUFI incorporates the newest findings regarding vapor diffusion and liquid transport in building materials and has been validated by comparison with field observations. Because WUFI can provide a day-by-day analysis of moisture movement based on actual weather data, it can be used to plot the characteristics of roof self-drying so that the analysis of condensation may be viewed as a long-term phenomenon. WUFI also allows the inclusion of the effects of solar radiation, which may be an important factor in roof self-drying.

Although WUFI obviously marks a significant step forward in building moisture analysis, it still may be subject to some of the same conservative, rule-of-thumb principles that characterized previous simplified approaches. As an example, the WUFI user must make assumptions regarding air movement within the building; and as discussed previously, the amount of air movement can have a dramatic effect on moisture transfer and the potential for condensation. As a result, it may be very easy to overestimate the amount of air movement and in turn overemphasize the potential for long-term condensation within a roof or other building assembly. In addition to issues regarding air movement levels, the current WUFI tool contains only limited data for popular North American roofing system components such as polyiso foam insulation.

Recent Roof Condensation Research

Because of new tools like WUFI, research into roof condensation has increased dramatically within the last few years. And because WUFI can incorporate solar radiation effects and the solar reflectivity of the roof surface, much of this research has been directed at how moisture movement is affected by a cool, highly reflective roof compared to a darker roof with low solar reflectivity. One of the first research studies to be published (Bludau et al. 2008) introduced two concepts regarding cool roofs. The first involves the reduction in internal heat gain caused by a highly reflective roof during the day, and the second involves nighttime radiation effects that can cool the roof surface below ambient air temperature. Modeling conducted in this study suggested that a white reflective roof installed over a layer of thermal insulation (in this case, polyisocyanurate) and a permeable (i.e. self-drying) metal deck in an extreme cold climate zone like Anchorage, Alaska, may accumulate moisture in the winter in excess of the amount of moisture that can be removed in the summer through self-drying. Modeling conducted on the same roof assembly in a less severe climate (Chicago) suggested that the amount of moisture in the roof system would tend to increase in the winter, but the self-drying process in the summer would still return the roof to its original moisture condition. A similar modeling study (Saber et al., 2011) which included a layer of wood fiber instead of polyisocyanurate foam suggested that excessive moisture accumulation would occur under white reflective roofs in northern locations such as Saskatoon, Saskatchewan and St. Johns, Newfoundland. However, modeling for a similar roof in Toronto showed no long-term moisture accumulation.

In the same time period of these modeling studies, several professional consultants began to investigate field reports of excessive moisture accumulation in cool roofing systems. Hutchinson (2009) summarized a number of anecdotal reports of roof condensation in cool roofs in and around Chicago. In all cases, the observation of condensation was associated with one or more roof design problems such as the use of a single layer of roof insulation or workmanship practices that allowed excessive air movement. In a similar manner, Dregger (2012) reported field observations of three cool roofs installed in California which also showed excessive moisture accumulation. All of these roofs were installed over plywood or OSB decks with no insulation above the deck; and Dregger concluded that the moisture accumulation observed could be attributed to a combination of a lack of thermal insulation above the roof deck and excessive air movement within the roof assembly. Dregger also suggested that the addition of a layer of insulation above the roof deck and under the roof membrane would have corrected this problem by moving the dew point below the roof deck and reducing air flow within the roofing system.

As a result of these initial modeling studies and field observations, a new level of experimental research was started to better understand the potential for excessive moisture accumulation in cool roofs. Ennis and Kehrer

(2011) conducted a study of mechanically-attached single-ply roofs installed in Chicago (the same location as Hutchinson's field observations), and used the results of the observations to conduct a modeling study using WUFI. In all cases, both black and white roofs modeled dried out completely by the summer even if small levels of moisture may have accumulated during the winter. In addition, Ennis and Kehrer observed that the WUFI modeling tended to predict a higher level of moisture accumulation in the white roof than actually observed during field observations. The researchers suggested that the difference between predicted and actual moisture accumulation may be due to a relatively high air exchange rate selected in the modeling to account for possible air movement due to billowing of the mechanically attached roof membrane.

In an effort to better quantify the amount of air intrusion in mechanically attached single-ply systems, the National Research Council of Canada (NRC, 2104) conducted an experimental observation of air movement using a large pressurization apparatus typically used for wind uplift testing of roofing systems. After measuring actual air leakage of various mechanically-attached single-ply systems, the NRC study concluded that leakage was negligible and well below the minimum ASTM and ICC standards for a building air barrier. As a result, the NRC research tends to confirm previous suggestions that the assumed air infiltration rate for mechanically-attached single-ply roofs is much higher than the amount of air infiltration that actually occurs.

Finally, a large-scale field study of cool single-ply roofs was conducted by Fenner et al. (2014). This study looked at cool mechanically attached single-ply roofs installed on 26 Target stores, all in colder climates, all more than 10 years old, all direct to steel deck, and half with only a single layer of insulation. Based on roof test cuts conducted at each store location, visible moisture was observed in only one roof; and this moisture was attributed to an observed external leak rather than internal condensation. A follow-up by this author, conducted using a portable humidity sensor in several Midwest Target stores during December 2014, suggests that the actual humidity in the stores in the winter may be lower than assumed in previous modeling studies. These anecdotal observations indicated that the average humidity in these stores in the winter month of December ranged from 25 percent to under 35 percent during outdoor temperatures from 25 to 30 degrees Fahrenheit.

Observations from Recent Research and Field Studies

Although frequently discussed in recent research and reports, moisture accumulation in roofs appears to be a relatively rare phenomenon tending to occur only in the presence of one or more severe conditions. These severe conditions may include:

- **Extremely cold external temperatures.** It is possible that such extreme temperatures may exist only in the northernmost areas of North America.
- **Extremely high internal temperature and humidity.** The observations of the complete lack of moisture accumulation in 26 roofs over Target stores suggests that actual winter humidity in typical retail, office, and warehouse occupancies may be significantly lower than assumed in several recent moisture modeling studies.
- **No insulation or a single layer of roof insulation above-deck.** The Dregger (2012) study of uninsulated roofs in California certainly suggests that some level of above-deck insulation should be used with any single-ply roofing membrane. In a similar manner, the Hutchinson (2009) reports of condensation associated with only a single layer of roofing insulation may suggest that two or more staggered layers of insulation should be installed under all single-ply roofs.
- **Unusually high levels of air movement within the roofing system.** Some of the modeling studies reviewed in this article suggest that high levels of air movement within a roofing system will contribute to moisture accumulation. However, recent NRC (2014) air barrier testing of mechanically attached single-plies suggests that modeling tools may easily overestimate the amount of air infiltration affecting the roof. As a result, they also may overestimate the potential for moisture condensation in roofs.

In addition to this brief review of the key conditions that may contribute to condensation and moisture accumulation in most if not all roof assemblies, it would be important to restate the benefits and risks of vapor retarders within roofing systems. Although a well-designed and installed vapor retarder can remove many of the concerns associated with moisture accumulation, they add new risks of allowing moisture accumulation from roof leaks and may severely limit important self-drying roof properties.

Recommendations for the Design Professional

Based on the review of moisture movement in roofing systems and the tools available to assess and mitigate roof condensation, the following strategies are recommended for the concerned design professional:

- **Establish a conservative but realistic estimate for actual interior humidity conditions within the building.** Although underestimating humidity conditions may lead to moisture accumulation within a roofing system, overestimating anticipated humidity conditions may unnecessarily point to the need for a vapor retarder and the loss of self-drying roof benefits.

- **Limit unnecessary air movement within the roofing system—both in the design of the roof and in the quality of roof installation.** The bad news here is that poor design and installation practices—like installing only a single layer of roof insulation and failing to close obvious gaps at penetrations and transitions in the roof assembly—will cause a high level of unwanted air infiltration that may lead to moisture accumulation. But the good news from the recent NRC (2014) study is that mechanically attached single-ply roofs using reinforced membranes significantly reduce air movement—even to the point that they could be considered air barriers by current building code criteria.
- **Include a minimum amount of above-deck thermal insulation beneath the roofing membrane.** The Dregger (2012) study of uninsulated roofs in California suggests that some minimal level of above-deck roof insulation should be installed with every cool single-ply roofing system, even in moderate climates. Dregger further suggests that above-deck insulation be installed even when not required by the building code.
- **Allow whenever possible the capability of the roof to "self-dry" in the event condensation does occur.** It's not that often that building designers are given a free gift like the self-drying roof concept, and it should not be discarded without considerable analysis.
- **Select roofing materials with low perm ratings and high resistance to moisture damage.** As illustrated in Table 1, there are many roofing materials available with low perm ratings, especially critical roof insulations that must resist moisture for many years. Using low perm materials can reduce the consequences of moisture accumulation in the event other factors fail to remain within your design assumptions.
- **Use modeling tools, but recognize their limitations.** In the case of the simplest tools, recent research clearly suggests that the answers they provide will almost always be overly conservative. In the case of more sophisticated tools like WUFI, it is vital that the designer understand the underlying assumptions and adapt these assumptions to actual expected conditions.

Footnotes

1. *Additional information about WUFI including a free software download may be obtained from Oak Ridge National Laboratory at http://web.ornl.gov/sci/btc/apps/moisture/index.html*

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Reducing Peak Electrical Demand

THE HIDDEN BENEFIT OF COOL ROOFS

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This paper reviews the concept of peak demand charges on electrical utility bills, and provides an analysis of the effect of cool or highly reflective roofs in reducing peak demand charges. The analysis suggests that peak demand charges may account for a significant portion of monthly electric bills across the United States and that cool roofs may provide an equally significant opportunity to reduce these charges when installed on air-conditioned buildings. The analysis also suggests that the peak demand and net energy savings offered by cool roofs are available for both new and existing conditioned buildings in all climates within North America.

Introduction

A sharp peak in electrical demand can be observed in almost every building during the busiest hours of the day. Although a share of this peak may be attributed to equipment used 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

Learning Objectives

1. Understand the difference between net usage and peak demand charges and the role each plays in your electric bill. Using examples of typical electrical bills, learn how to identify and separate these two charges.
2. Understand how peak demand charges are affected by thermal loads on your building and, most importantly, the roof on your building. Recognize the key types of thermal loads that have the greatest influence on peak demand charges.
3. Understand how cool roof surfaces can be used to reduce peak demand - and related peak demand charges - in almost any climate.
4. Learn to estimate potential peak demand charge savings for different roof systems using the free online “Cool Roof Peak Calculator” developed by the U.S. Department of Energy and Oak Ridge National Labs.

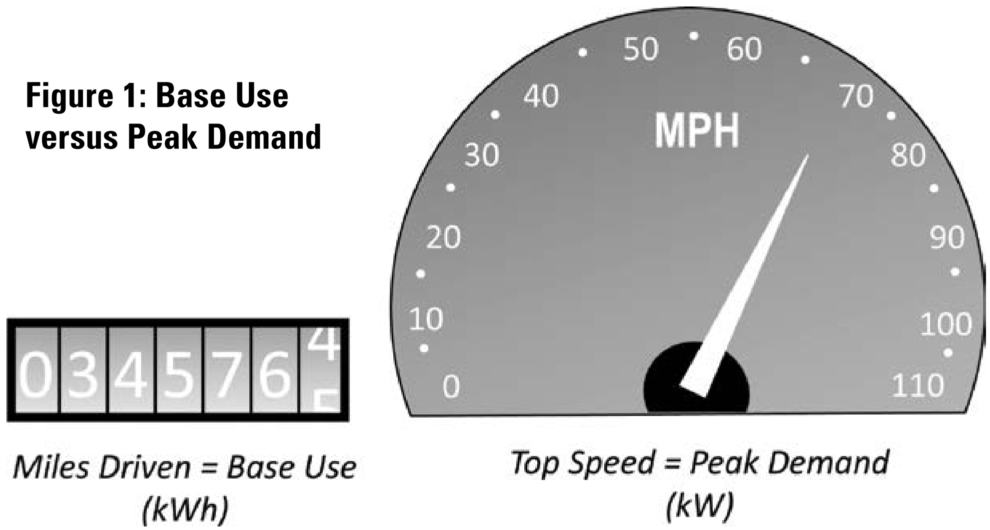
power plant capacity, causes imbalances in the power grid, and may result in increased air pollution. But most importantly for the building owner, peak demand may result in monthly charges many times higher than base electrical rates. One of the best approaches to shrink peak demand is to reduce the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

In an effort to help building owners and designers deal effectively with peak electrical demand charges, this article provides a step-by-step review of all aspects of peak demand, including how to identify peak demand charges on a typical commercial electrical bill, how to estimate the potential savings achieved when installing a cool roof, and how to achieve other business and community benefits associated with reducing the peak energy demand. This information may be especially important since few articles to date on building energy savings have adequately addressed peak-demand issues.

How Businesses Pay for Electricity: Base Use and Peak Demand

Although it may be convenient to focus simply on the bottom line of an electric bill, monthly electricity costs are composed of two distinctly different types of charges. The

Figure 1: Base Use versus Peak Demand



first is base energy use, which measures the total quantity of electricity supplied for the billing period. The second is peak energy demand, which measures the highest amount of power supplied at any one time within the billing period. Base energy use is measured in kilowatt-hours (kWh), while peak energy demand is measured in kilowatts (kW). One way to help understand the relationship between base energy use and peak demand load is to use the analogy of an odometer and speedometer in a car. As illustrated in Figure 1, the base amount of energy used (kWh) can be compared to miles driven, as shown on the odometer, while peak energy demand (kW) would be similar to the top speed driven, as shown on the speedometer.

Like the highest speed achieved during a trip, peak demand seldom occurs for more than a few hours, or fractions of hours, during each billing period. Typically, peak demand charges are based on the amount of energy consumed in a specified period of time known as a demand interval. Demand intervals are usually 15 or 30 minutes. To calculate a customer's demand, the electric company takes the demand interval with the highest energy consumption in kilowatt hours (kWh), and divides by the length of the demand interval in hours. Mathematically, the hours cancel, leaving kilowatts (kW) as the units of peak demand.

Peak demand charges are a relatively new phenomenon in electric billing, but the concept of peak demand is closely related to a number of well-known electric power failures in the United States, including the state of California in 2000 to 2001 and the city of Chicago in 1995. In both of these cases, peak demand for electricity during prolonged heat waves exceeded the capacity of the electric grid, causing frequent brown-outs as well as occasional complete failure of the electric grid. In response to the severe effects when peak demand exceeds the capability of the electric grid, governments and utilities began to look for ways to reduce peak demand. This, in turn, has led to the incorporation of demand charges in many utility bills. As a result, many electric utilities across the United States now incorporate some level of peak demand charges in their monthly bills. To provide an example of how widespread the practice of peak demand billing has become, a simple Google search for "understanding peak demand" will generate links to peak demand charge information from electric utilities in California, Florida, Illinois, Indiana, Maryland, Massachusetts, New York, Ohio, and Pennsylvania. As an additional example, the U.S. Utility Rate Database[1] maintained by the U.S. Energy Information Administration identifies hundreds of utility companies across the United States that currently incorporate peak demand charges in their monthly bills, especially for high-use commercial and industrial customers.

Base Use Versus Peak Demand: Looking At Your Electric Bill

Because electricity is not easily stored, utilities must have adequate capacity to meet customers' maximum requirements, both for the quantity of total level of base energy needed and for the highest level of peak demand required. As a result, commercial and industrial electric rates across the country frequently are designed to cover the cost of providing both base and peak energy. However, identifying these two cost components on the average commercial electrical bill may be a little difficult, especially when most bills are subdivided into a large number of special fees and adjustments. Figure 2 shows a typical commercial electrical bill containing both base use and peak demand charges, as published by an Indiana-based electrical utility[2].

Figure 2: Base Use and Peak Demand Charges on a Sample Commercial Electric Bill (Source: Duke Energy1)

Name/Service Address	For Inquiries Call	Account Number
Acme Enterprises Attn: Accounting Dept. 123 Main Street Hanover, IN 47243	Duke Energy 1-800-655-5555 For Account Services, please contact Betty Smith	0000-1234-05-6

Meter	Number	Reading Date From	Reading Date To	Days	Meter Reading Previous	Meter Reading Present	Usage	Actual kW
Elec	012345600	Jun 28	Jul 27	29	144441	15860	56,780	120.00

Base Use (kWh)

Peak Demand (kW)

Duke Energy Rate HSND – High Load Factor Sec S/v			
Other Charges & Credits		8.12	
Demand Charge 120.00 kW @	$ 14.0600000	1,687.20	
Energy Charge 56,780 kWh @	$ 0.01683000	955.61	
Rider 60 – Fuel Adjustment 56,780 kWh @	$ 0.01420700	806.67	
Rider 61 – Coal Gassification Adj 120.00 kW @	$ 1.91436100	229.72	
Rider 62 – Pollution Control Adj 120.00 kW @	$ 2.04057600	244.87	
Rider 63 – Emission Allowance 120.00 kW @	$0.00032300	18.34	
Rider 66 – DSM Ongoing 56,780 kWh @	$ 0.00021600	12.26	
Rider 68 – Midwest Ind Sys Oper Adj 56,780 kWh @	$ 0.00072500	41.17	
Rider 70 – Reliability Adjustment 56,780 kWh @	$ 0.00035700	20.27	
Rider 71 – Clean Coal Adjustment 120.00 kW @	$ 2.06452600	250.14	$ 4,274.38
	Total Current Electric Charges		$ 4,274.38

Base Use Charges

Peak Demand Charges

Total Base Use: $0.0330 / kWh
Total Peak Demand: $20.10 / kW
Total Net Billing: $0.075 / kWh

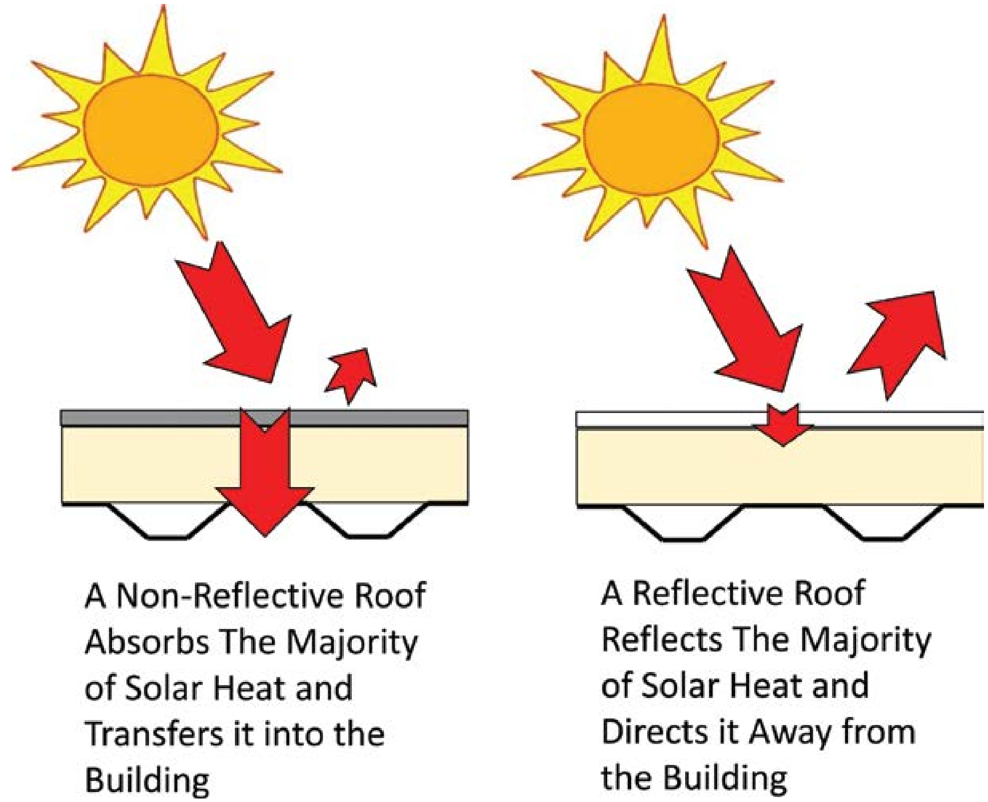
Near the top of the sample bill, monthly base energy use (circled in green) is shown to be 56,780 kWh. In the detail section of the bill, this base energy use is multiplied by a base energy charge as well as additional charges for fuel adjustments, demand side management (DSM) fees, regional system operator adjustments, and reliability adjustments. Altogether, these base energy use-related charges (also circled in green) add up to a total monthly base use charge of $0.033 per kWh.

However, this base fee accounts for less than half of this total monthly electric bill. Also near the top of the bill, peak demand (circled in red) is shown to be 120 kW. In addition to the base use fees discussed previously, the 120 kW of peak demand is multiplied by a basic peak demand charge plus additional demand-related charges for coal gasification adjustments, pollution control adjustments, emission allowances, and clean coal adjustments. Altogether, these peak demand-related charges (also circled in red) add up to a total monthly demand charge of $20.10/kW.

After calculating base use and peak demand charges, we also may calculate the total electricity rate for this customer. For this bill, the total monthly charge is divided by the 56,780 kilowatt hours used, yielding an effective rate of $0.075/kWh, or over twice as much as the nominal base usage rate of $0.0330. It should be noted that this total electric usage rate of $0.75/kWh is actually among the lowest commercial rates available in in the United States. According to the U.S. Energy Information Administration, average electric rates by state for commercial users in 2013 ranged from a low of $0.07/kWh in Idaho to a high of $0.15/kWh in New York[3].

As illustrated by this sample bill, peak demand charges may account for a significant portion of a business's monthly electrical costs. As a consequence, building owners frequently are interested in learning how these costs may be reduced, especially through the use of energy-efficient building design and operating strategies.

Figure 3: Reflective versus Non-Reflective Roof



How Can You Reduce Peak Energy Demand?

As mentioned in the introduction to this article, peak energy demand for the majority of buildings occurs in the late afternoon, as occupant and building heat loads also tend to crest. For commercial facilities operating primarily during normal business hours, a number of key factors may help reduce the daily demand peak for electrical power. First, the ubiquitous use of electrical equipment in modern buildings may add to both base and peak demand for electricity. Electrical equipment may include motors associated with manufacturing operations as well as office equipment such as computers, copying machines, etc. Reductions in peak equipment demand may be achieved through the elimination of unnecessary equipment or by using equipment with improved electrical efficiency.

Excessive amounts of indoor lighting also add to base and peak electricity requirements. As a consequence, reducing the amount of lighting used during peak periods

Table A: Current Cool Roof Reflectance Standards[4]

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 24 Energy Standard (2012)	n/a	0.63

can be a useful strategy to reduce peak demand. Reductions in peak demand related to lighting can be achieved by reducing ambient lighting levels and installing task lighting, supplementing electric lighting with daylighting from windows and skylights, and installing more efficient light fixtures using fluorescent or LED technologies.

Although improvements in equipment and lighting may help reduce overall electrical demand, an important driver of peak demand in many commercial buildings is related to the spike in air conditioning requirement loads during the heat of the afternoon. Similar to equipment and lighting loads, peak air conditioning loads may be reduced by improving the efficiency of air conditioning systems or simply by turning up the thermostat. However, peak demand for air conditioning also may be addressed by reducing the impact of climate-related thermal loads on the building. In the case of air conditioning loads generated by high outdoor temperatures, overall air conditioning demand can be reduced by installing additional wall and roof insulation and thermally efficient doors and windows. But a certain amount of the peak in daily air conditioning demand is related to the direct rays of the sun rather than outdoor ambient air temperatures. This means that reducing solar loads by reflecting solar heat away from the building may offer one of the best ways to reduce peak electricity demand in modern buildings.

Fortunately, we have a well developed and effective technology available today to help reduce solar loads in buildings: the reflective or “cool” roof. Cool roofs use a highly reflective surface to direct a significant portion of solar heat from the sun away from the building. Unlike a dark or non-reflective roof surface that absorbs and transfers solar heat into the building, a light-colored, reflective roof surface reflects and drives solar heat away from the building and into the atmosphere.

Cool roofs also are available using a wide variety of roofing technologies, including single-ply membranes, cool-surfaced modified asphalt systems, metal roofing panels, and a wide variety of roof coatings that may be applied to many different roofing surfaces. However, 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 on the aging of the sample tested. Table A provides a brief summary of these new and aged reflectance percentages for three of the most-recognized building codes and standards.

Because cool roofing has become a very popular roofing choice, roofing manufacturers typically identify the reflectivity of their products in technical data sheets and brochures. In almost all cases, these measures of roof reflectance are based on standards developed by the U.S. EPA EnergyStar program[5] or the ANSI/CRRC-1 cool roof standard developed by the Cool Roof Rating Council[6]. In addition, both the U.S. EPA and the Cool Roof Rating Council maintain online databases where you can look up the initial and aged reflectivity of many roofing products.

Peak Demand: Not Just a Warm Climate Problem

In order to better understand the benefits of cool roofs in reducing peak energy demand, researchers at Oak Ridge National Laboratories[6] examined the seasonal variation in peak air conditioning demand for a variety of different climates across North America. Their findings suggest that even though base cooling demand may be higher in hot climates as compared to cooler climates, almost all climates exhibit a seasonal variation in the peaks for roof-related air conditioning demand. Figure 4 compares this seasonal trend for a hot, cooling-oriented climate (Phoenix, Ariz.) and a cold, heating-oriented climate (Minneapolis, Minn.).

Although Phoenix exhibits a higher and more consistent monthly demand for air conditioning as compared to Minneapolis, demand falls off at the beginning and end of the year for both cities, with a substantial portion of peak demand located within a six-month period from April to September. As a result, it may be possible to reduce peak demand in both cities using cool roofing technologies. In fact, a recent study of cool roofs and peak demand costs suggests that the potential for roof-related peak demand savings for hotter cities like Phoenix and colder cities like Minneapolis may be approximately identical[7]. Figure 5 illustrates the comparative base energy and peak demand savings for the seven major climate zones in the U.S. identified in this study.

Although the colder climate zone for Minneapolis offers little or no savings potential in terms of base use, the opportunity for peak demand savings is approximately the same as in much hotter climate zones. Although it may seem counter-intuitive that similar peak energy savings may be achieved in cold climates as well as hot climates, Figures 4 and 5 taken together may help explain this apparent paradox. In a hot location such as Phoenix, even though overall cooling loads are very high, the seasonal peak is less pronounced, while the seasonal peak in a cold location such as Minneapolis is much more pronounced even though the overall cooling loads are smaller. In effect, peak demand savings in hot climates may be described as a smaller piece of a larger pie, while peak demand savings in cold climates may be described as a larger piece of a smaller pie.

Beyond the Dollars: Other Costs of Peak Energy Demand

So far we have discussed the immediate economics of peak demand, but there are other costs associated with peak demand that should be discussed as well. Because additional electrical generating capacity is required to meet peak demand levels, it is likely that this will lead to increased atmospheric pollution and environmental impacts due to the need to construct new generating facilities as well as the less-than-efficient operation of existing facilities. Peak energy demand also is strongly associated with the overall heating of large cities and urban areas, commonly referred to as the Urban Heat Island Effect. In turn, increased warming of urban areas may lead to increased production and accumulation of ground-level ozone, which in turn may lead to increased

Figure 4: Ratio of Monthly to Annual Peak in Roof-Related Air Conditioning Demand (Source: Oak Ridge National Laboratories7)

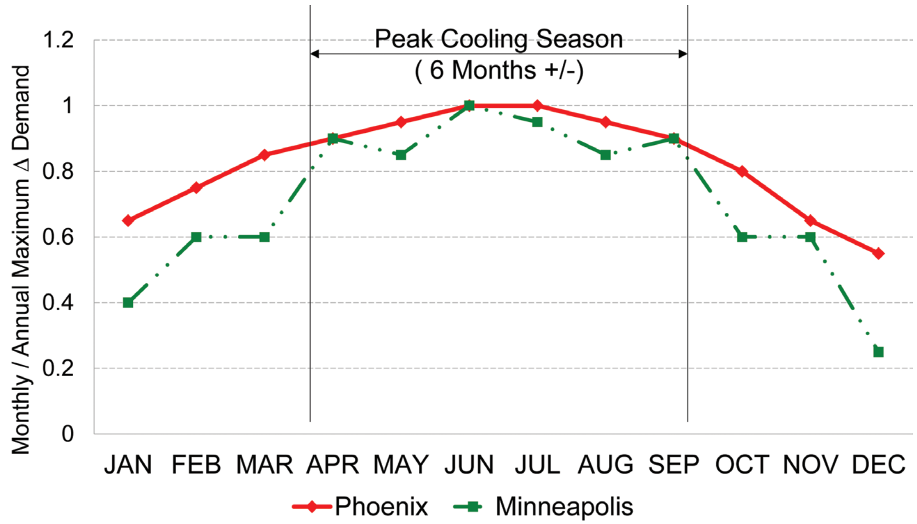
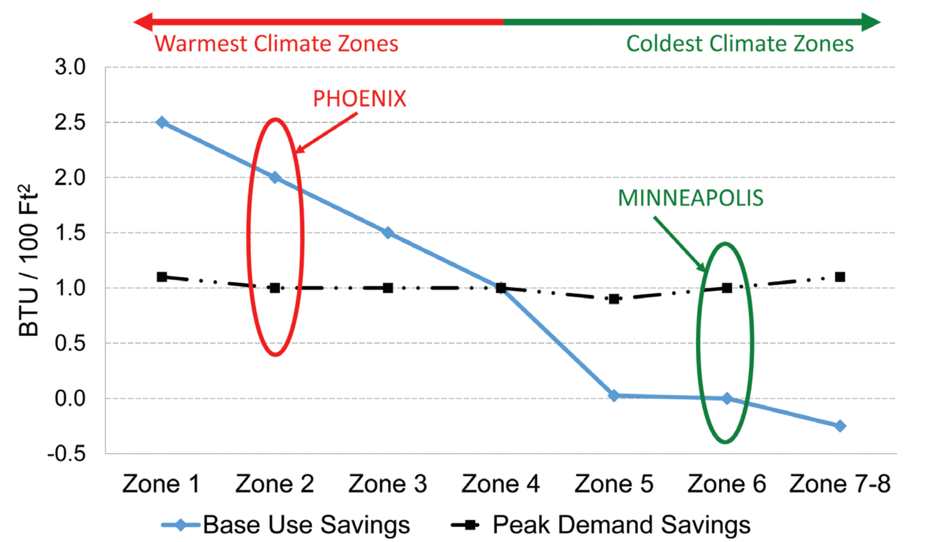


Figure 5: Roof-Related Base Use and Peak Demand Savings by North America Climate Zone (Source: RoofPoint Energy and Carbon Calculator8)



health risks and a growing number of "Ozone Action Days" in cities and towns across North America. Finally, increasing peak electricity demand may increase the potential for "brownouts," especially during unusually hot weather events.

How to Estimate Peak Demand Savings

The good news for building owners and designers is that the U.S. Department of Energy has developed an online calculator specifically designed to evaluate peak demand and cool roofs: The Cool Roof Peak Calculator[9]. This online calculator, developed by Oak Ridge National Laboratory, provides a fast and easy way to compare the overall energy costs and savings for a wide variety of roof and building conditions. The calculator is easy to access and comes with step-by-step instructions for the user. Because the DOE Cool Roof Peak Calculator includes climate data for over 200 cities across North America, it's easy to find a model location that can match up with almost any site in the United States or Canada. Unlike some energy calculators that model steep slope residential roofs with attics, the Cool Roof Peak Calculator models the typical low slope commercial roof with insulation placed directly over the deck and under the roofing membrane.

Figure 6 provides an illustration of a partial screen shot of the Cool Roof Peak Calculator from the Web site of Oak Ridge National Laboratory.

Figure 6: The DOE Cool Roof Peak Calculator[9]

DOE Cool Roof Peak Calculator
(http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm)

My State — Select a State
My City — Select a City
My Proposed Roof:
R-value (HIGH=20; AVG=10; LOW=5) [h·ft²·°F/Btu]
Solar reflectance, SR (HIGH=80; AVG=50; LOW=10) [%]
Infrared emittance, IE (HIGH=90; AVG=60; LOW=10) [%]
My Energy Costs and Equipment Efficiencies:
Summertime cost of electricity (HIGH=0.20; AVG=0.10; LOW=0.05) [$/KWh]
Air conditioner efficiency (COP) over cooling season (HIGH=2.5; AVG=2.0; LOW=1.5)
Energy source for heating (choose one)
If electricity, wintertime cost (HIGH=0.20; AVG=0.10; LOW=0.05) [$/KWh]
If fuel, cost (Natural gas: HIGH=1.00; AVG=0.70; LOW=0.50) [$/Therm]
(Fuel oil: 2002 East coast=0.85; 2002 Midwest=0.70) [$/Therm]
Heating system efficiency (Furnace or boiler: HIGH=0.8; AVG=0.7; LOW=0.5)
(Electric heat pump: HIGH=2.0; AVG=1.5) (Electric resistance: 1.0)
My Electricity Demand Charges and Duration:
Demand charge during cooling season (HIGH=15.00; AVG=10.00; LOW=5.00) [$/KW]
Months charged for peak demand (Typical = 6) [-]

Total Annual Energy + Demand Savings (relative to a black roof) [$/ft² per year]
Cooling energy savings [$/ft² per year]
Heating energy savings (heating penalty if negative) [$/ft² per year]
Cooling season demand savings [$/ft² per year]

Using the DOE Cool Roof Peak Calculator is simple and straightforward, but some specific information is required to operate the calculator effectively. To obtain the maximum benefit from the calculator, the user must identify the following building attributes and conditions:

1. **Location.** The user first must select a U.S. state or Canadian province and then select the closest city

from a list provided for each state and province. As an example, the state of Ohio includes data for Akron, Cleveland, Dayton, Mansfield, Toledo, and Youngstown. For all states, an ample number of model cities is provided to allow the user in other cities to make an accurate climate-based comparison.

2. **Proposed Roof R-Value.** If the calculator is being used by a building or roofing professional familiar with past and current energy codes, it is likely that the roof R-value may be estimated based on the age of the roof or building. For the non-professional, the calculator instructions provide suggestions for "high," "average," and "low" insulation R-value levels across North America.
3. **Proposed Roof Reflectance.** Roof reflectance is stated as a ratio similar to the values shown in Table A. Roof reflectance for a specific roofing product may be obtained from roofing manufacturer data sheets or from the EPA Energy Star or Cool Roof Rating Council Web sites mentioned previously. Once again, the calculator provides suggestions for "high," "average," and "low" roof reflectance values. It should be noted that the aged reflectance value should be used in order to accurately estimate the long-term ability of the roof to reflect solar energy.
4. **Proposed Roof Infrared Emittance.** Roof emittance is also stated as a ratio similar to roof reflectance. A full discussion of emittance is beyond the scope of this paper, but essentially it is a measure of the amount of solar energy absorbed into the roof but eventually transmitted back to the atmosphere rather than into the building. Roof emittance for a specific roofing product may be obtained from roofing manufacturer data sheets or from the EPA Energy Star or Cool Roof Rating Council Web sites mentioned previously. Once again, the calculator instructions provide suggestions for "high," "average," and "low" roof reflectance values. However, the values shown on the calculator may provide a much wider range than typically found in most low-slope roofing membranes. Typically, the thermal emittance of common single-ply and asphaltic roof coverings runs within a range of 0.75 to 0.90.
5. **Base Energy Costs.** The calculator assumes that the building is being heated in the winter and cooled in the summer, but the user must identify the types of fuel used to heat and cool the building as required. Because the calculator assumes electricity will be used to cool the building, the user must enter the "summertime" cost of electricity in $/kWh, which is identical to the base use rate discussed previously. (Note that the peak demand charge for electricity is entered later in the calculation.) Next, the user must indicate the type of fuel (electricity, natural gas, or fuel oil) used to heat the building as well as the wintertime cost of the fuel. In the case of electricity, the cost is measured in $/kWh and is the same as the base

use rate as determined from an electric bill. For natural gas and fuel oil, the cost is measured in therms. Again, the calculator instructions provide a suggested range of typical fuel prices across North America.

6. **Equipment Efficiencies.** After identifying the types of fuel and their corresponding unit costs, the user must enter the efficiency for the air conditioning and heating equipment used in the building. Suggested efficiencies are provided in the calculator instructions.
7. **Electricity Demand Charges and Duration.** Finally, the user must enter the peak demand charge for the building, measured in $/kW. As discussed previously, this demand charge should be determined from a recent electric bill as illustrated in Figure 2. In addition, the user must enter the duration of the peak air conditioning season for the building, which typically is a six month peak cooling season, as illustrated in Figure 4.

Based on the information provided by the user, the Cool Roof Peak Calculator then will provide an estimate of the total roof-related energy and demand savings for the building and roof system selected. In addition, this total cost amount is broken down into three key cost components:

- **Cooling Energy Savings.** This amount includes total air conditioning savings from both base use and peak demand reductions.
- **Heating Energy Savings/Heating Penalty.** This amount includes any changes in overall heating costs due to the cool reflective roof. Essentially, this estimate helps to account for any heating losses incurred in winter when solar radiation that could help heat the building is reflected back into the atmosphere.[10]
- **Cooling Season Demand Savings.** This is an estimate of the reduction in peak demand charges due to roof reflectivity. The amount shown is included in the cooling energy savings previously identified.

It is important to note that all costs provided by the calculator are stated in dollars-per-square-foot of roof area. As a result, these costs must be multiplied by the total square footage of roof surface area to estimate annual cost savings for the entire building.

It is also important to note that the DOE Cool Roof Peak Calculator is designed to compare the total roof-related net energy costs for a cool roof with a reflectivity as specified by the user to a black roof with a solar reflectance of 0.05 (5 percent). If the user wishes to compare two cool roofs with different reflective ratings, the user may run separate calculations on each roof and manually compute the difference in savings between the two roofs.

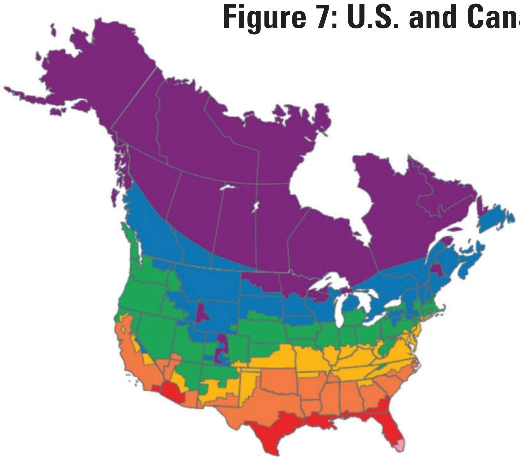


Figure 7: U.S. and Canada Climate Zones[11]

Climate Zone	Model Cities
1	Miami (FL)
2	Houston (TX), Phoenix (AZ)
3	Atlanta (GA), Dallas (TX)
4	St. Louis (MO), Baltimore (MD)
5	Chicago (IL), Pittsburgh (PA)
6	Milwaukee (WI), Minneapolis (MN)
7-8	Duluth (MN)

Applying the Cool Roof Peak Calculator

Now that we've reviewed the basic workings of the Cool Roof Peak Calculator, we can examine in greater detail what the calculator may reveal about base use and peak demand savings throughout the U.S. and Canada. Although it is difficult to accurately estimate exact base use and peak demand without a detailed examination of the construction and cost conditions for a specific building, it may be possible to develop a useful model by applying conservative assumptions suitable to a wide array of locations and buildings across North America. In order to develop an informative portrait of peak demand and cool roofs throughout the U.S. and Canada, this paper provides a climatic analysis for a typical cool roof versus a black roof using the following parameters applied to the Cool Roof Peak Calculator:

- **Climate Zones and Model Cities.** Current energy codes divide the U.S. and Canada into eight primary climate zones, with Zone 1 being the warmest, and Zone 8 the coldest. Within each zone, demand for heating and air conditioning tends to fall within a relatively narrow range, allowing for a similar thermal analysis of buildings within the climate zone. A map of the eight climate zones in the U.S. and Canada is illustrated in Figure 7.

  Also included in Figure 7 is a listing of model cities used within the analysis. In the case of the most extreme zones, only one city has been selected since the zones are either small or sparsely populated. In the intermediate climate zones, however, two cities were selected and their climate data averaged to provide a more accurate representation for all cities within the zone.
- **Representative Commercial Building.** Within all climate zones, a representative building was selected. For the purposes of this analysis, the building was assumed to be a low-rise structure of one or two stories with a flat roof area of 20,000 square feet. In addition, it was assumed that the building was cooled with an electric air conditioning system with a Coefficient of Performance (COP) of 2.0 and heated with a natural gas-fired furnace[12] with an efficiency rating of 70 percent.

- **Roof Insulation (R-Value) Level.** Two insulation conditions were selected for the analysis to allow for a comparison of different roofing scenarios. The first condition ("new insulation") assumes that the existing roof is completely removed and replaced with a new roofing system using R-value levels meeting the latest energy code requirements. The second condition ("old insulation") assumes that the existing roof and insulation remains in place and is simply recovered with a new roofing membrane with no additional R-value. The new insulation condition is intended to model the installation of a completely new roof on an existing building or a newly constructed building, while the old insulation condition is intended to model the installation of a roof recovery over an existing roof that remains in place. Because the amount of roof insulation used in buildings varies according to climate zone, lower levels of insulation were assumed for the warmer climates and higher levels were assumed for colder climates. In addition, because code-mandated insulation levels have increased over the past decade, separate insulation levels were applied to the old and new insulation conditions. For the old insulation condition, R-value levels were based on an earlier (2006) version of the International Energy Conservation Code, and for the new insulation condition, R-value levels were based on the most recent (2012) edition of the code.

Table B: Old and New R-Values by Climate Zone

Climate Zone	Roof R-Value: Old Insulation[1] Condition	Roof R-Value: New Insulation[2] Condition
1	10	20
2	15	20
3	15	20
4	15	25
5	15	25
6	15	30
7 & 8	15	35

Notes:
1. Per 2006 International Energy Conservation Code
2. Per 2012 International Energy Conservation Code

These old and new insulation levels are summarized by Climate Zone in Table B.

- **Roof Reflectance/Emittance.** The long-term reflectance of most cool roofs tends to fall within a relatively narrow range, specifically from 0.55 to 0.63 for minimum aged reflectance as shown in Table A. Accordingly, the cool roof modeled in the analysis is based on a reflectance of 0.60, which falls approximately mid-range of the aged values

Figure 8: Estimated Net Energy Savings: Cool Roof Installed over Existing (Old) Insulation* (Annual Dollars/20,000-Square-Foot Roof Area)

*Old insulation values based on 2006 International Energy Conservation Code (IECC)

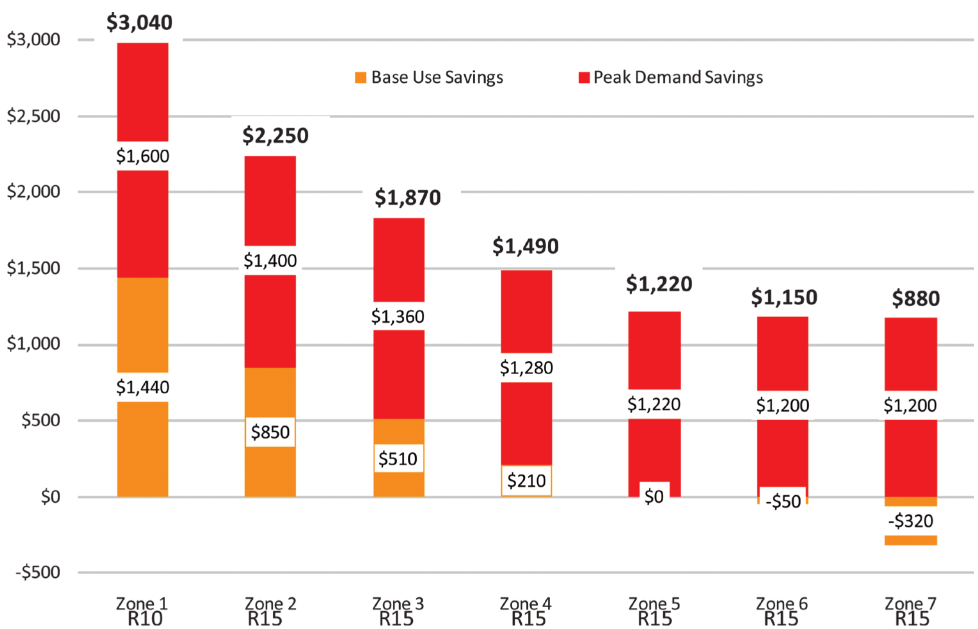
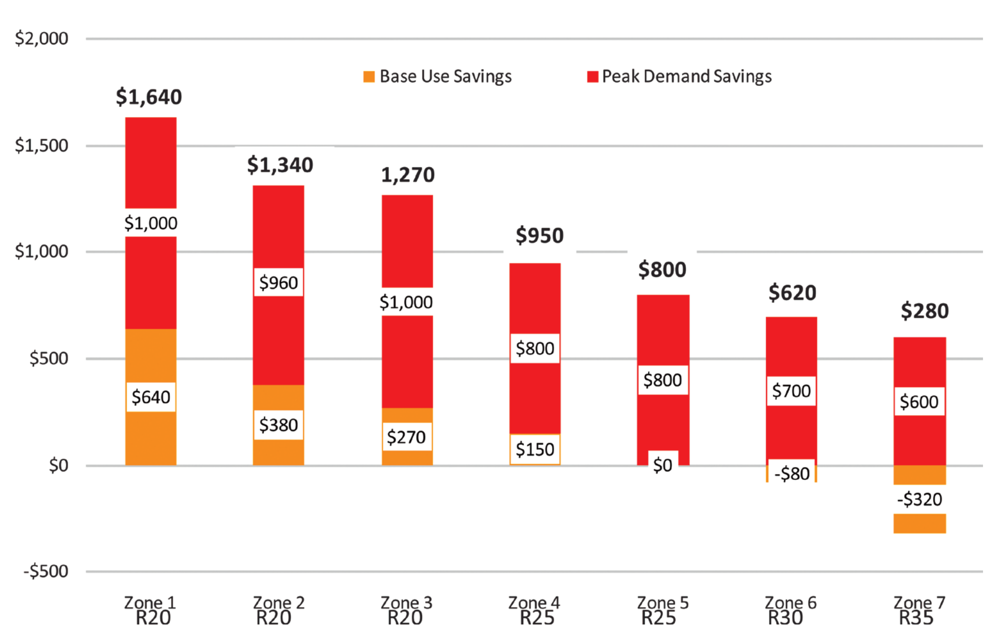


Figure 9: Estimated Net Energy Savings: Cool Roof Installed over New Insulation (Annual Dollars/20,000-Square-Foot Roof Area)

*New insulation values based on 2012 International Energy Conservation Code (IECC)

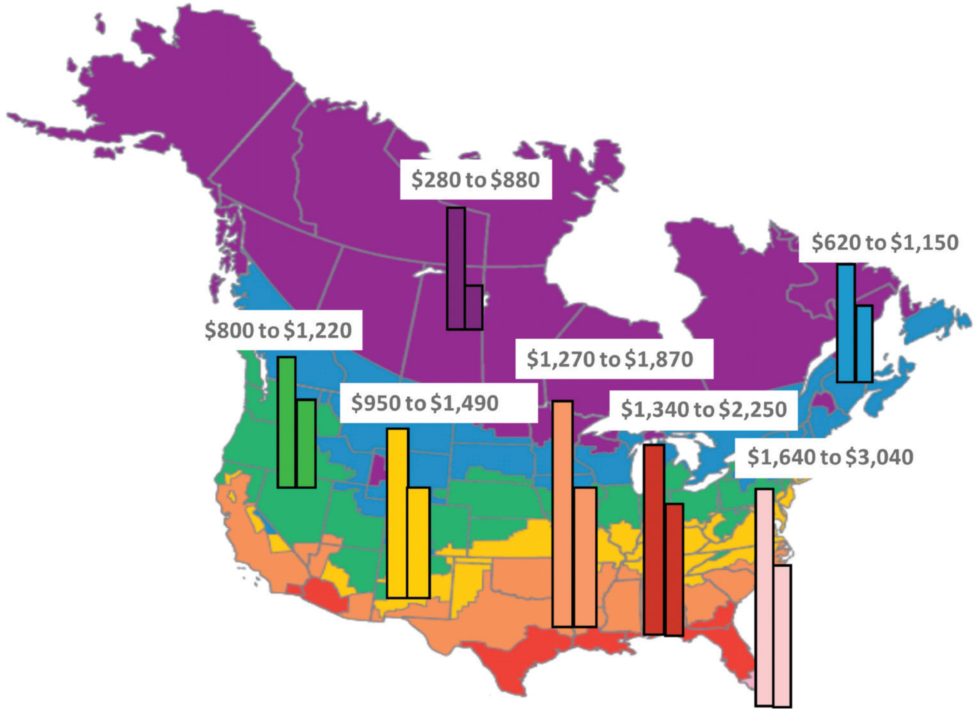


in Table A. And because the Cool Roof Peak Calculator automatically compares this cool roof to a black roof with a reflectance of 0.05 and an emittance of 0.90, an emittance value of 0.90 also was selected for the cool roof.

- **Base Use and Peak Demand Charges.** Because the example electric bill from the state of Indiana shown in Figure 2 represents one of the lower rates available in North America, a comparison based on those rates obviously would provide a conservative estimate. As a result, the analysis assumes a base use rate of $0.033/kWh and a peak demand charge of $20.10/kW across all eight major climate zones. In addition, the analysis assumes a rate of $0.70/therm for natural gas, which is very close to the average commercial rate across North America at this time.

Using these assumptions and values, estimated base use and peak demand savings for a typical 20,000-square-foot commercial building in all eight climate zones were calculated using the DOE Cool Roof Peak Calculator. For each climate zone, two different roof conditions were examined. The first set of calculations compared a cool roof against a black roof installed over new roof insulation meeting the most recent energy code R-value requirements. The second set of calculations compared the same cool and black roof installed over existing (old) roof insulation meeting an earlier version of the energy code. The comparison of the cool versus black roof over new roof insulation is shown in Figure 8, and the comparison of the cool versus black roof over old insulation is shown in Figure 9. In addition, the range of savings available for both old and new insulation conditions is graphically portrayed on a map of the eight North America climate zones in Figure 10.

Figure 10: Estimated Range of Net Energy Savings for a Cool Roof by Climate Zone (Annual Dollars/20,000-Square-Foot Roof Area)



The Bottom Line: Cool Roofs and Peak Energy Demand Savings in all Climates and Conditions

As illustrated in Figures 8 through 10, the total value of base plus peak energy savings offered by the cool roof is sizeable, averaging more than $1,000 annually in most climate zones for a typical commercial building. In addition, these savings appear to be equally important for buildings with either “old” and “new” levels of insulation. As a consequence, cool roofs may offer a significant opportunity for net energy savings even at the highest levels of roof insulation mandated by the latest building codes. The savings value of cool roofs is further reinforced because modern cool roofing membranes frequently cost no more that darker non-cool roofs. As a result, all of the savings identified in the analysis tend to drop to the bottom line without any additional cost encumbrances.

Cool Roofs and Insulation Level

Differences in the level of new versus old insulation appear to have a significant effect on the amount of base use savings. In most cases, base use savings using the lower R-value levels of old insulation are reduced by half or more by the addition of the higher R-value levels of new insulation. However, this condition does not appear to hold for peak demand savings. In most cases, the savings available using either old or new insulation levels appears to be significant for all climate zones. As a consequence, it would appear that significant reductions in peak demand cost cannot be achieved simply by increasing insulation levels without also installing a cool roof covering.

Peak Demand Drives the Savings

One of the most striking results from this analysis is that the estimated savings due to peak energy demand reduction provide a substantial majority of the net energy savings throughout all climate zones studied. In fact, peak demand savings account for over 50 percent of total savings in the warmest climate zones up to 100 percent in the coldest climate zones. In addition, while base use savings tend to vary widely by climate zone (even falling to negative values in the coldest climates), peak demand savings tend to be more significant and consistent throughout all climate zones. As a consequence, the analysis suggests that any estimate of cool roof savings that neglects to include peak demand reduction has little chance of providing an accurate estimate.

Effect of Fuel Selection on Net Energy Savings

As stated previously, a natural gas forced air system was selected as the heating system for the building in these calculations. If electric resistance heat or an electric heat pump were selected in lieu of a natural gas system, the base use savings (shown in yellow in Figures 8 and 9) would decrease slightly due to an increased winter heating penalty applied to the electric heating system. In a similar manner, if an oil-fired furnace were selected in lieu of the natural gas system, the base use savings would increase slightly due to the higher cost of heating oil as compared to natural gas across the country. However, the peak demand savings (shown in red in Figures 8 and 9) would remain the same regardless of the heating system and fuel source selected.

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2. *Derived from "Understanding Your Utility Bill: A Guide for Businesses in Indiana." Duke Energy, Plainfield, Indiana (2013). Available http://www.duke-energy.com/pdfs/understand-bill-guide-in.pdf*
3. *2013 Retail Commercial Electrical Rates by State (excluding Alaska and Hawaii) from U.S. Energy Information Administration "Electricity Data Browser." For more information on average electric rates, please visit http://www.eia.gov/electricity/data/browser/*
4. *Although stated as a percentage in this table, roof reflectivity is typically expressed as a ratio in reference standards. Initial values shown are based on measurements of roofing material as manufactured, while aged values shown are based on measurements after field exposure of test samples.*

5. *For more information on the Energy Star rated roofing products, please visit http://www.energystar.gov/productfinder/product/certified-roof-products/*

6. *For more information on Cool Roof Rating Council rated roofing products, please visit http://coolroofs.org/products/results*

7. *Petrie, T. W., Wilkes, K. E., & Desjarlais, A. O. (2004). "Effects of Solar Radiation Control on Electricity Demand Charges – An Addition to the DOE Cool Roof Calculator." Proceedings of the Performance of the Exterior Envelope of Whole Buildings IX International Conference, December 5-10, 2004.*

8. *Hoff, J. L. (2014). "Introducing the RoofPoint Energy and Carbon Calculator: A New Modeling Tool for Roofing Professionals." Proceedings of the Second International Roof Coatings Conference, Baltimore, MD, July 14-17, 2014.*

9. *U. S. Department of Energy (DOE) Cool Roof Peak Calculator. Available http://web.ornl.gov/sci/roofs+walls/facts/CoolCalcPeak.htm*

10. *It should be noted that the Cool Roof Peak Calculator does not account for the potential for snow cover of the roof in the winter. The presence of accumulated snow on the roof surface may have two effects on overall energy savings. First, snow on either a cool or a dark roof surface will reduce the amount of solar energy absorbed into the building, which may increase heating costs. Conversely, a thick accumulation of snow may provide additional thermal insulation that may reduce heating costs.*

11. *Climate zones as defined by the International Energy Conservation Code and ASHRAE 90.1. Illustration courtesy of the Center for Environmental Innovation in Roofing and the Polyisocyanurate Insulation Manufacturers Association.*

12. *Natural gas was selected because it provides over 60 percent of all commercial building heating demand in the United States, according to the Commercial Building Energy Consumption Survey (CBECS) published by the U.S. Energy Information Administration (http://www.eia.gov/consumption/commercial/)*

Take the quiz online: http://thececampus.com/BEWINTER15Quiz

Disclosure: The Newest Dimension in Green Building

NEW TOOLS LIKE EPDS AND HPDS ADD OPPORTUNITIES AS WELL AS CHALLENGES FOR BUILDING DESIGNERS

By Dr. James L. Hoff, DBA

Whether you're perusing the latest edition of an architectural magazine or viewing an online green building blog, the word disclosure is certain to catch your eye. With the release of the latest version of the LEED Green Building Rating System (LEED v4), disclosure has taken center stage as the next big topic in the ongoing discussion of how green building is defined. And sharing the stage with disclosure are new tools such as EPDs and HPDs that have emerged to help measure the "greenness" of building products. In order to understand disclosure's eventual impact on building design and practice, it is important to start with a review of how the concept developed and how it is related to other important green building concepts.

Many different stakeholders within the building community have been active in the promotion of disclosure, but they all tend to share the same questions. A particular building material may help save operating energy, but how does it impact other equally important environmental concerns? A product may have a high recycled content, but after the effort required to salvage, transport and convert the material, is there still a tangible net environmental benefit? Beyond specific environmental concerns, how does the product affect the safety, health and wellbeing of building occupants? Unfortunately, many of these questions cannot be answered effectively using current tools such as energy calculators and one-dimensional green product certifications.

Learning Objectives

1. Understand the key underlying concepts of material disclosure and transparency.
2. Identify the newest product disclosure requirements incorporated in the latest versions of popular green building standards, codes and guidelines.
3. Review the important features and details of these new disclosure requirements, with an emphasis on Environmental Product Declarations (EPDs) and Health Product Declarations (HPDs).
4. Review how and when these new disclosure requirements will be introduced into the construction marketplace.

Each of these questions is related to common concerns held not only by green building advocates but also the entire building design community: Do we have the kind and quality of information about building products to make informed decisions? Do simplistic claims or categories of "greenness" help or hinder our analysis? Do current manufacturer data sheets and reports provide adequate information? Finally, do we understand exactly what goes into the building materials we use and how these ingredients may affect the wellbeing of building occupants?

Although disclosure offers an opportunity to move from guesswork to informed decision making, it is important to recognize that it remains a work in progress, raising perhaps as many questions as answers. In order to help answer some of these questions, this article will strive to provide a balanced review by focusing on two of the most talked-about tools: The Environmental Product Declaration (EPD) and the Health Product Declaration (HPD).

Environmental Product Declarations (EPDs)

EPDs have been around the longest of all the new product disclosure tools, and the current procedures to develop EPDs have been in place for more than a decade. However, the fact that even the best-established disclosure tool is still relatively new attests to how quickly the concept of disclosure has entered the construction market. At the same time, the current EPD process has been built on a solid, science-based approach that examines total environmental impact over the entire life cycle of a product. There are many excellent definitions of EPDs, but for the purposes of this article, the EPD may best be described as a tool that discloses recognized environmental impacts over the life cycle of a product using quantifiable measures in accordance with globally recognized procedures. This definition should be especially useful after we break it down and examine its key elements.

Recognized Environmental Impacts. The environmental impacts reported by EPDs are based on a universally recognized listing of impact categories established by the U. S. Environmental Protection Agency. This listing, called the Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI), categorizes a number of key environmental impacts related to the release of various chemicals into the atmosphere, ground and water. Currently, five of the impacts are included in the data provided by most EPDs. Table 1 provides a listing of these five impact categories along with a brief description of their effects.

In addition to these primary environmental impact categories, EPDs also include an analysis of the energy consumed during the product's life cycle and classify this energy into renewable and non-renewable sources. In addition, EPDs include data regarding water and other resource consumption, as well as information about hazardous and non-hazardous waste generated over the product life cycle.

Quantifiable Measures. All of the data reported in an EPD are also quantified based on the best current science in order to allow for comparison of environmental impacts among similar products. In the case of the five key TRACI impact categories, these measures are based on chemical or molecular values that can be added to the impacts of other products to help establish an overall environmental "footprint" for a combination of products, such as a building or major building component. Table 2 provides a listing of the specific metrics associated with each TRACI impact category.

In all cases, the specific chemical selected is used as a common denominator for similar chemicals that produce a similar result. As an example, although carbon dioxide (CO2) is the most-recognized greenhouse gas, the TRACI tool allows for the conversion of other greenhouse gasses such as methane (CH4) and ozone (O3) into the equivalent amount of CO2 that would cause the same effect. Because the TRACI measures accommodate the range of chemicals associated with environmental impact, these measures can be added to the impacts of other products to establish an overall environmental "footprint" for a whole building constructed from these products. The additive nature of

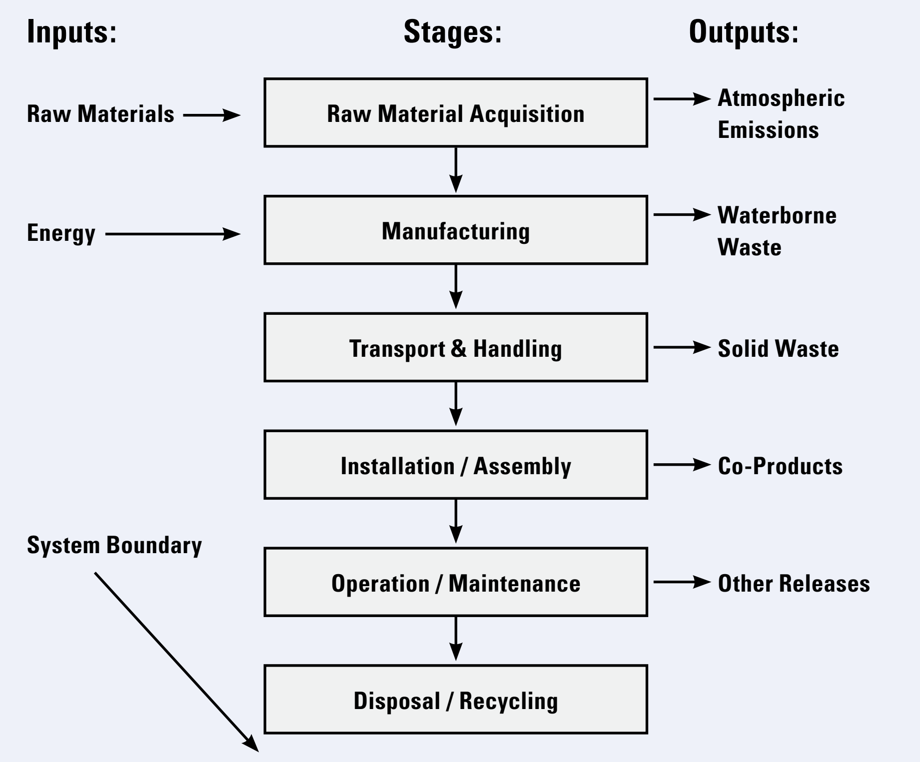
Table 1: Typical EPD Environmental Impact Categories (From U.S. EPA TRACI)

Environmental Impact Category	Description of Effect
Global Warming Potential (GWP)	Impact of greenhouse gasses that increase global temperatures
Ozone Depletion Potential (ODP)	Impact of chemicals that adversely affect the earth's upper ozone layer
Eutrophication Potential	Impact of chemicals that pollute rivers and lakes by removing oxygen
Smog Creation Potential	Impact of chemicals that contribute to ground level ozone and smog
Acidification Potential	Impact of chemicals that produce acid rain

Table 2: Typical EPD Environmental Impact Measure (From U.S. EPA TRACI)

Environmental Impact Category	Impact Measure
Global Warming Potential (GWP)	Kilograms (kg) of carbon dioxide (CO_2) or equivalent
Ozone Depletion Potential (ODP)	Kilograms (kg) of Freon (R11) or equivalent
Eutrophication Potential	Kilograms (kg) of nitrogen (N) or equivalent
Smog Creation Potential	Kilograms (kg) of ozone (O_3) or equivalent
Acidification Potential	Moles of positive ions (H^+) or equivalent

Figure 1: Product Life Cycle Diagram



EPD data is very important in the development of impact calculators such as the Athena Impact Estimator used to assess the environmental impacts of whole buildings or major subsystems.

The Product Life Cycle. The assessment and measurement of the environmental impacts reported in an EPD are structured to include all aspects of a product's life cycle, from the initial acquisition of raw materials to the eventual removal and disposal of the product. This life cycle typically is described in an EPD using a diagram similar to Figure 1.

Key elements of the product life cycle include the identification of all resource inputs (raw materials, energy, water, etc.) and all environmental outputs (atmospheric emissions, waterborne waste, solid waste, etc.) associated with the key stages of the product life cycle (raw material acquisition, transport, manufacture, installation, maintenance, removal, disposal, etc.). The diagram also typically includes a system boundary to indicate exactly what processes are covered within the life cycle assessment. As an example, the system boundary for many consumer products does not include the operation or use of the product, while almost all building material EPDs include maintenance and operational impacts within the system boundary.

Recognized Procedures. In addition to utilizing quantifiable and well-known measures of environmental impact based on established science, EPDs are conducted in accordance with the requirements of rigorous international standards. In almost all cases, these procedures are based on standards adopted and maintained by the International Standards Organization. Some of the ISO standards relevant to EPDs include:

- ISO 14044 Environmental Management - Life Cycle Assessment - Requirements and Guidelines.

- ISO 14025 Environmental labels and declarations - Type III Environmental Declarations - Principles and Procedures.
- ISO 21930 Sustainability in Building Construction - Environmental Declaration of Building Products.

The use of well-established procedures helps assure that the information disclosed in an EPD has been developed in an objective and scientific manner. In fact, the type of EPD required by LEED and other green building guidelines requires a final third-party review to validate the disclosure for accuracy and reliability.

EPDs in Codes and Standards

EPDs are included as part of the newest LEED Green Building Rating System (LEED v4) under Option 1 of Credit MRc2 ("Building Product Disclosure and Optimization: Environmental Product Declarations"). In this option, LEED credit may be awarded for projects that incorporate at least 20 products covered by EPDs. Full credit is available for products covered by product-specific declarations, while ½ credit is awarded for products covered by a generic industry declaration.

EPDs also may soon become part of other well-known green building codes and standards. Recently, the inclusion of EPDs has been proposed as an addendum to the ASHRAE 189.1 Standard for the Design of High-Performance Green Buildings, and the addendum is currently undergoing public comment and review. In addition, many observers anticipate that a similar proposal to add EPDs will be submitted as part of the 2014 code hearings for the 2015 version of the International Green Construction Code (IgCC).

Benefits and Limitations of EPDs

Benefits. Based on the previous discussion, it should be obvious that the key benefits of EPDs are related to the quantitative, scientific and standardized approach used in their development. This combination of sound measurement, good science and recognized procedure certainly helps to assure the validity and reliability of the environmental data contained in EPDs. And because of the quantifiable basis for all measurements, the data for a specific product can be added to the data for other products to obtain a relatively reasonable picture of the overall environmental impact of whole buildings and major subassemblies. Finally, the measureable values contained in EPDs can be used not only to compare products but to improve existing products. In fact, one of the original rationales for the development of EPDs was to develop useful tools to drive continuous product improvement.

Limitations. Of course, the benefits of EPDs come with a price; and price itself is the first limitation. Based on my own experience in helping different manufacturers and trade associations develop EPDs, I can tell you the entire process is very expensive. Typically, an initial EPD for an average roof or wall product may cost in excess of $100,000 after you include all expenses associated with the life cycle assessment and the development of product category rules for the specific product.

Along with the upfront dollar costs, the complexity of the development process may be viewed as an additional limitation. For starters, the inherent complexity of EPDs combined with the current lack of overall environmental impact data means that it is possible for different EPD practitioners to obtain different results using the same basic procedures. More importantly, because construction and design professionals usually aren't chemists by training, it may be very challenging to select building products simply based on factors such as CO2 equivalents or moles of H+ ions.

Finally, although EPDs offer a way to compare the environmental aspects of building products, they currently fail to address more specific issues involving human health. And because of this limitation, the Health Product Declaration (HPD) is being developed.

Health Product Declarations (HPDs)

Compared to the EPDs, the HPD is a brash newcomer, with the first HPD standard formally published just a few

Who's Driving the Product Disclosure Movement?

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Although many forces are involved in promoting transparency in the green building market, the marked increase in demand for product disclosure has been affected significantly by the following three groups:

- **LEADING ARCHITECTURE AND DESIGN FIRMS. Many of the leading global architecture firms have established formal policies regarding product disclosure and how they will work with product manufacturers in the future. As of the beginning of 2014, more than two dozen of the largest architectural firms in the United States have released letters formally requesting EPDs, HPDs or similar product disclosure from manufacturers who supply products specified by these firms. And the request has some teeth behind it. Although the specific consequences vary from firm to firm, materials manufacturers who fail to develop EPDs and HPDs for their products may face restrictions on making presentations to a firm's staff, exclusion from product libraries and losing preference in project specifications.**

years ago. As a result, the most significant difference between EPDs and HPDs involves the degree of rigor and standardization in their underlying processes. Where EPDs rely on scientific method and quantifiable measurement, HPDs rely less on certainty and more on precaution. In fact, one of the founding values of the HPD is the precautionary principle, which advocates for the restriction or elimination of products if there is any concern about their safety. In addition, the measurements used in HPDs may be considered much less quantifiable than EPD metrics. Rather than providing a measurable effect on health impact, the HPD simply identifies the presence or absence of specific chemicals. As with EPDs, there are many definitions of HPDs; but in light of our previous definition of the EPD, the HPD may best be described as a tool that discloses product ingredients and known/suspected health hazards associated with these ingredients, based on a variety of reference sources.

Product Ingredients. Without a doubt the most critical feature of the HPD is the full disclosure of all ingredients in a building product. Because many building materials, especially materials other than liquids such as coatings or adhesives, are not specifically subject to current Material Safety Data Sheet (MSDS) regulations, manufacturers are under no obligation to disclose the specific ingredients in their products. And even though many building materials manufacturers do in

Who's Driving the Product Disclosure Movement?

CONTINUED FROM PREVIOUS PAGE

- **THE GREEN BUILDING MEDIA.**
  Within the past 10 years, the number of new media sources promoting green buildings has expanded almost exponentially. From magazines, newsletters, blogs and other social media, these green building commentators have become very visible and persuasive advocates for increased building product transparency.

- **THE GREEN DATA AGGREGATORS.**
  Dozens of organizations have jumped into the growing business of collecting and compiling green product information. New groups like Green Wizard and Pharos have developed online tools to help building designers compare and select products based on the ingredients they contain and how they can be used to meet new LEED material credits. And established organizations like Underwriters Laboratories (UL) and NSF (formerly the National Sanitation Foundation) are rapidly expanding their traditional product certification listings to include the latest in green product disclosure.

fact voluntarily provide MSDSs for their products, procedures regarding the disclosure of important health impacts that may be relevant to the building designer are not well established. As a result, the HPD offers a more standardized approach to the disclosure of ingredients. Current HPD standards also allow for the use of proprietary ingredients without disclosing the specific chemical or mixture as long as the health hazards are clearly identified and disclosed.

Reference Sources. After a product's chemical ingredients have been identified in an HPD, these chemicals must be screened against a variety of reference lists which identify any health hazards known or suspected to be associated with the ingredients. Frequently, these lists are referred to as being "authoritative" because many of the lists have been established by leading national and global bodies based on the best science available. However, these lists may vary significantly in terms of their recognition and scope. Some examples of current HPD "authoritative" lists are shown in Table 3.

It should be noted that Table 3 provides only a partial listing of current HPD reference sources. The full listing in the current HPD Open Standard includes more than one dozen compilers and more than two dozen specific lists.

Known/Suspected Hazard. For any chemical flagged by one or more of these lists, specific hazard warnings are provided by the list compiler. Similar to hazard warnings on the MSDS, these warnings identify hazards related to specific health concerns, such as cancer, reproductive toxicity, developmental toxicity, etc. Table 4 provides a selected listing of typical hazard language associated with a selection of current HPD reference lists.

Table 3: Examples of HPD "Authoritative" Lists and Other Sources

Source	List(s)
U. S. Environmental Protection Agency (EPA)	Integrated Risk Information System Database (IRIS), Chemicals of Concern Action Plans
European Commission (EU-ECHA)	Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)
International Agency for Research on Cancer (IARC)	Monographs On the Evaluation of Carcinogenic Risks to Humans
State of California	Proposition 65 Chemicals Known to the State to Cause Cancer or Reproductive Toxicity (Prop 65)
San Antonio Statement	San Antonio Statement on Brominated and Chlorinated Flame Retardants

Table 4: Examples of HPD Hazard Statements

Source	List(s)
U. S. EPA / IRIS	"Reproductive or Developmental Toxicity (A, B, C)"
U. S. EPA / Action Plans	"Action or Work Plan Chemical"
E.U. / REACH	"PBT, vPvB, POP, SVHC, REACH Annex XVII"
IARC / Cancer Monographs	"Carcinogen or Likely Carcinogen (A, B1, B2, B3, C)"
California Proposition 65	"Known by the State to cause...."
San Antonio Statement	"Flame retardant substance class of concern for PBT and long range transport"

After screening each chemical ingredient against the hazard references, all known and suspected hazards as identified by these lists must then be reported as part of the HPD.

HPDs in Codes and Standards

HPDs are included as part of the newest LEED Green Building Rating System (LEED v4) under Option 1 of Credit MRc4 ("Building Product Disclosure and Optimization: Material Ingredients"). In this option, LEED credit may be awarded for projects that incorporate at least 20 products covered by HPDs or similar disclosures. Like EPDs, HPDs also may soon become part of other well-known green building codes and standards. Many observers anticipate that one or more proposals about HPDs will be submitted as part of the 2014 code hearings for the 2015 version of International Green Construction Code (IgCC).

Benefits and Limitations of HPDs

Benefits. Undoubtedly the biggest benefit offered by the HPD is its low cost to produce. In contrast to the exhaustive science required to develop an EPD, the time and effort to develop an HPD is much less demanding. Because product manufacturers already possess a reasonable understanding of their ingredients and have access to data from their raw material suppliers, the effort required to produce an HPD differs little from the work needed to produce the common Material Safety Data Sheet (MSDS). Based on the experiences of several manufacturers who participated in a pilot trial of HPDs in 2012, completing the first HPD may take a day or two. And after the first HPD is finished, it is likely that additional HPDs can be completed in less than a day. Because the time and resources required to complete an HPD are relatively small, the cost per HPD may be calculated in the hundreds of dollars rather than the tens of thousands of dollars required to prepare and publish an EPD.

Along with low cost, HPDs also offer an innate simplicity not available with EPDs. Instead of reviewing dozens of complex measures involved in quantifying a broad range of environmental impacts, the sole function of an HPD is to identify the presence or absence of known or suspected health hazards. As a consequence, HPDs may be more suitable for the non-scientist to review and use. As stated by Russell Perry, FAIA, of architectural firm SmithGroupJJR:

"We do not need everyone to be an industrial hygienist in order for (HPDs) to be a valuable contribution to the building industry. We are not scientists in all of this, and we don't need to be. We're not making risks assessments. We're simply saying we have to get what these products consist of out into the world." ("Taking a Stance on Transparency," ECOBUILDING Pulse, Oct. 4, 2013.)

Limitations. The most obvious limitation of the HPD relates to its infancy as a standard. Unlike widely recognized standard processes such as ASTM, ANSI and ISO, the HPD protocol was developed using an "open standard" approach advanced by a coalition of health-oriented building advocates. This protocol, called the HPD Open Standard, was developed primarily by representatives of the founding sponsors with little or no formal public participation. In addition, material manufacturers did not directly participate in the development of the standard, but rather were relegated to a pilot trial of standard that was for the most part in its completed form. As a result, many of the guiding principles of standard consensus processes — open participation, balanced stakeholders, consideration of all viewpoints and the availability of an appeals process — were not included in the development of the current HPD protocol.

Perhaps as a result of the limited consensus process involved, the current HPD Open Standard includes a number of weaknesses and discrepancies. First, the current HPD standard fails to clarify if it is necessary to report chemical ingredients that are effectively transformed or consumed during manufacturer. As an example, the production of polyurethane products such as foam insulations, coatings and sealants requires the use of MDI, a chemical considered hazardous when directly exposed to humans. But for polyurethane products produced in the confines of a factory (such as rigid polyiso foam insulation), all of the MDI is consumed and transformed into a resultant cellular foam that itself contains no MDI. In a similar manner, several red lists include styrene as a chemical health hazard, but polystyrene building materials (the typical EPS and XPS foams used for building sheathing and insulation) do not directly contain styrene.

The lack of clarification in HPDs also is challenging in regard to chemical mixtures. Many popular roof and wall products rely on the use of materials that may be considered hazardous when airborne, but in almost all cases these materials are firmly encapsulated into a larger chemical matrix that poses little or no risk of release into the building environment. Examples of such materials include titanium dioxide (TiO_2), which is a key component in almost all "cool" roofing products, and carbon black, which is a key ingredient in rubber roofing membranes and sealing gaskets. Some hazard lists such as California Proposition 65 even include wood dust as a hazard. Does that mean we should identify all wood products to be hazardous?

The lack of clarification regarding ingredients is further compounded by the broad and disparate collection of "authoritative" lists used to identify hazard. Some of these lists, such as the EU REACH protocol, are widely acclaimed and accepted throughout the world. In most cases, this acceptance is due to the high levels of science and consensus used to develop the list. Others, such as California Proposition 65, are more regional in scope and in many cases are simply derivative collections of hazards identified by other lists. Some of the lists, like the U.S. EPA Work Plan List, do not actually identify a known hazard but rather are used to identify materials that are being subjected to further government review. Finally, some of the lists, such as the San Antonio Statement, are not actually lists but rather a public statement of opinion by a group of concerned individuals. But regardless of the level of recognition each "authoritative" list has achieved, the hazards they identify must be treated as equal threats within the HPD reporting protocol. As a result, many products that contain absolutely no hazardous chemicals as identified by the world's most recognized authorities still must be identified as hazardous if they contain any ingredient included in the dozens of less-recognized lists and sources covered within the current HPD framework.

Taken as a whole, the potential for product exclusion within the current HPD Open Standard protocol may be significant for many segments of the building material industry. As an example, the HPD for the majority of commercial roofing products will likely include the disclosure of at least one ingredient alleged to be hazardous by one or more of the "authoritative" lists. Table 5 provides a listing of these roofing products, the alleged hazards they may contain and the reference list from which the alleged hazard is identified.

Table 5: Modern Roofing Products and Alleged Hazards (Per HPD Open Standard)

Roofing Product	Alleged Hazard	Reference List
Thermoplastic Roofing Membranes (PVC and TPO)	Titanium Dioxide (TiO_2)	California Prop 65
EPDM Roofing Membrane	Carbon Black	California Prop 65
Built-Up and Modified Bitumen Roofing Membranes	Bitumen	California Prop 65
Reflective Metal Roofing	Titanium Dioxide (TiO_2)	California Prop 65
Reflective Roof Coatings	Titanium Dioxide (TiO_2)	California Prop 65
Asphaltic Roof Coatings	Bitumen	California Prop 65
Wood Fiber Insulation	Wood Dust	California Prop 65
Polystyrene Insulation (EPS and XPS)	Brominated Flame Retardants	San Antonio Protocol, EU REACH
Polyiso Insulation	Chlorinated Flame Retardants	San Antonio Protocol
Spray Foam (SPF) Insulation	Chlorinated Flame Retardants	San Antonio Protocol

This table, which includes every major commercial roofing material available in today's market, may help illustrate one more concern about the current HPD Open Standard. When I have raised examples of products in this table to several leading green building advocates, their response has been, "Well, I'm sure the HPD Open Standard doesn't intend to flag all these products as hazardous. After all, many of these ingredients, like TiO2 or wood dust or carbon black, in roofing materials will likely never affect building occupants." This argument may be valid, but how will manufacturers respond in their published HPDs? As an example, if a building product manufacturer produces a product containing even a theoretical portion of any California Proposition 65 listed ingredient (and there are more than 400 of them!) and fails to list the ingredient on their product labels and literature, they could be in legal jeopardy for failing to comply with the specific reporting requirements of Prop 65. And past experience from California suggests that there are plenty of law firms just looking for the opportunity to initiate a Prop 65 lawsuit. As a result, I doubt that any product manufacturer will fail to report these ingredients and their alleged hazards in the HPDs they publish.

And how will building designers respond to HPDs that contain hazard warnings about cool roof coatings, wood, carbon black and the like? They will now be in possession of information stating the products they plan to specify contain ingredients potentially hazardous to the health of the clients. As a result, the inclusion of so many chemicals that may only be remotely connected to actual occupant health hazard could easily damage the credibility of the HPD as an objective and effective tool. In simpler terms, if the HPD flags every building product as hazardous, the relevancy and usefulness of the tool will be lost.

The final and perhaps most critical limitation of the current HPD Open Standard is the lack of risk assessment to accompany the current hazard identification. Stated simply, many materials may be considered potentially hazardous, but a useful understanding of the actual hazard requires an assessment of the risks involved. Some of the key elements of risk assessment currently lacking in the HPD Open Standard include:

- Threshold Level. At what level does exposure actually produce adverse health effects? Using toxicological science and experimental evidence, a maximum threshold level can be established, usually with a significant margin of safety (MOS) typically in the thousands.
- Exposure Path. How can any particular hazardous ingredient directly affect building occupants? In the case of many roof and wall products, especially exterior products or materials such as insulation that are enclosed within walls and roofs, the potential for exposure will likely be very low.

Unfortunately, the current HPD protocol provides little or no information to that may help a building owner or designer make decisions based on the actual risk posed by a building product.

Potential Alternatives to HPDs

As the building industry starts to digest the nuances of the new HPD Open Standard, the need for important changes to the standard are becoming apparent. Definitions regarding ingredients need to be broadened to accommodate a wide variety of real-world situations. And the "authoritative" nature of some of the reference lists needs to be examined. Finally, the concept of hazard needs to be expanded to include risk, especially if HPDs are to move up to the level of science and rigor established by EPDs.

Although many new initiatives to advance product health disclosure will focus on improving the current HPD process, other initiatives will focus on the development of better alternatives. Currently, two potential alternatives are available that may help address some or all of the limitations of HPDs. These alternatives include the new Safety Data Sheet (SDS) and the Product Transparency Declaration (PTD).

Safety Data Sheet (SDS). Even before the HPD Open Standard was developed, the world already was in the middle of a significant transformation regarding the reporting of product hazards. This transformation involved the harmonization of all product safety reporting across the globe using the new Globally Harmonized System (GHS) sponsored by the United Nations. In accordance with recent U.S. government regulations, the new GHS standard will be required for all materials currently subject to product safety reporting. This new GHS data format will be called the Safety Data Sheet (SDS) and will replace the previous Material Safety Data Sheet (MSDS) starting in 2014.

Although a comprehensive review of the SDS is beyond the scope of this article, many observers have noted that the information contained in the SDS is virtually identical to the HPD, with the exception that only the most authoritative sources are used for hazard screening. Naturally, because all product manufacturers have spent considerable time and effort developing an entirely new portfolio of SDSs, it may be prudent to ask why this new disclosure method — which will be available much faster than the HPD — should not be used as a unified standard for product ingredient and hazard disclosure.

Product Transparency Declaration (PTD). In an effort to expand the scope of HPDs to include risk analysis in addition to hazard identification, the Resilient Flooring Institute has recently developed a new Product Transparency Declaration (PTD). Starting with many of the same reference lists as the HPD Open Standard, the PTD protocol provides for an additional assessment of actual risk or exposure of each ingredient in its intended building function. Although the HPD protocol will be more complex than the current HPD standard, it may add considerable value and help establish product health disclosure on a similar scientific level as the EPD. As a testament to the potential value of the PTD concept, an immediate effort has been started at ASTM to transform the current PTD format into a consensus-based ASTM standard similar in scope to previously mentioned ISO standards for EPDs.

Closing Observations

Although this article has identified a number of limitations of EPDs and HPDs, it is important to recognize that everyone associated with green building agrees that increased transparency is a good thing. At a minimum, environmental and health declarations will provide a better understanding of the building material supply chain and how it may impact our environment and health. And hopefully this understanding will grow as we continue to refine and improve the reporting standards and protocols. Finally, and perhaps most importantly, increased product disclosure will help drive continuous improvement of the building materials we use.

At the same time, judgments concerning the suitability of any particular building product or comparisons among products will remain difficult and unpredictable. As a consequence, any building designer seeking to apply the information in EPDs and HPDs should always consider the risks involved. These risks include the possibility of overlooking important factors or tradeoffs, as well as the risk of arbitrary exclusion of otherwise excellent products and suppliers.

Perhaps the best recommendation going forward is to be proactive in the process — but cautious with the results. Yes, we should all agree that increased disclosure is a good thing, and we need to get the process started. But we also should keep in mind that our tools are very new and still unproven in application. As our industry starts to engage in a new level of product disclosure and review, it will be important to avoid oversimplification, especially if it may lead to sweeping changes in product selection. To avoid oversimplifying the challenges we face, it will be important to continually emphasize science, best practice and continuous improvement as the best tools for assessing and selecting sustainable building products.

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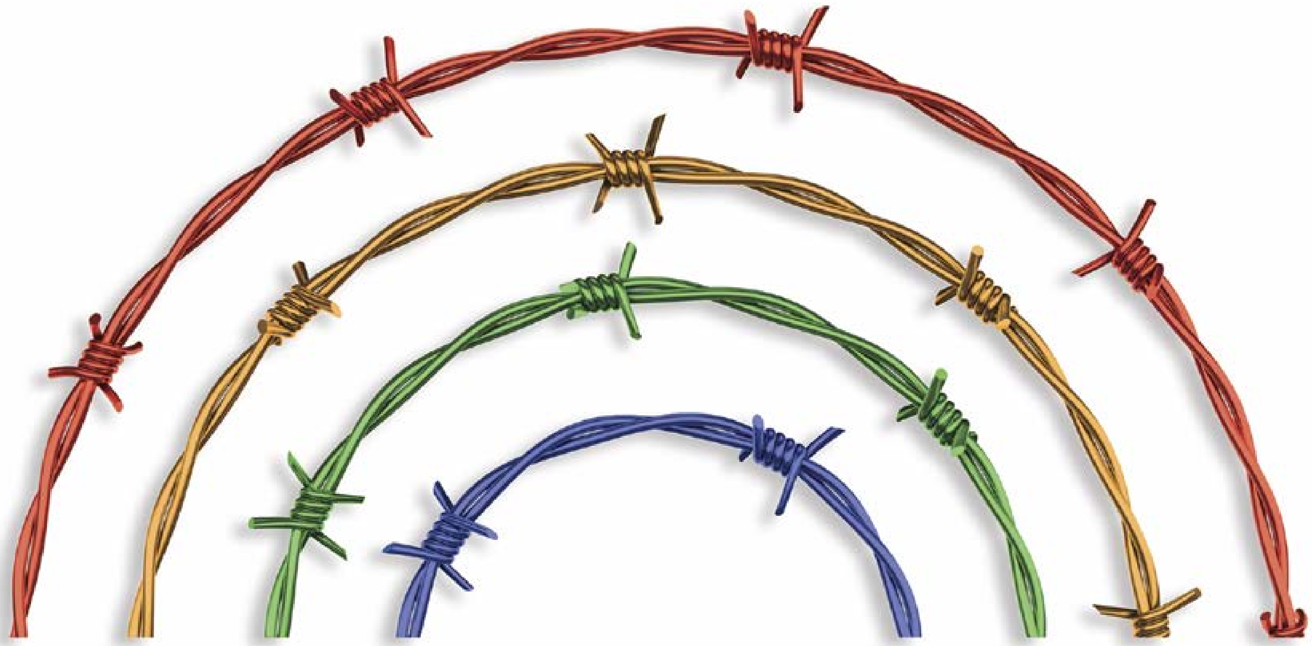

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