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# Environmentally Sensitive and Energy-conscious Roofs

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**Doorways** **to the** ***Future***

## ABSTRACT

The Cool Roofing Symposium in Atlanta in 2005, sponsored in part by the RCI Foundation, was a catalyst in the industry in regards to cool roofing. Recent spikes in the cost of energy have similarly sparked a new interest in ways to save energy. In addition, code mandates have affected change in the way consultants design roof systems. This paper will review the building and roofing industry's response to these conditions, as well as new research and materials, including cool ballast, cool metal coatings, and high thermal value insulation applications. Case studies of actual projects which have aspired to be both environmentally sensitive and energy efficient as well as new product reviews will be presented.

## SPEAKER

**TOM HUTCHINSON** is a graduate of the University of Illinois with masters degrees in both architecture and civil engineering. Mr. Hutchinson is a licensed architect and registered roof consultant specializing in roof design, contract document preparation, specifications, inspections, and the determination of moisture penetration and failure of existing roof systems. He has made numerous presentations in Europe, South America, North America, and Asia. His topics have included architectural contract detailing for roof systems, roofing removal and replacement, steep-slope roof systems design, roof restoration, and roof system maintenance. Mr. Hutchinson believes in the complete integration of all building components into a roof system design, and his work is noted for its comprehensiveness in design, detailing, and specification. Mr. Hutchinson is currently a principal in Hutchinson Design Group, Ltd., immediate past president of RCI, Inc., a Certified Energy Professional in the City of Chicago, and Secretary CIB/RILEM International Joint Committee on "Roof Materials and Systems." He is a member of AIA, CSI, RCI, NRCA, and ASTM Committee D-08 on Roofing, Waterproofing, & Bituminous Materials and past president of Barrington Rotary and region director of RCI.

# Environmentally Sensitive and Energy-conscious Roofs

## INTRODUCTION

Prior to any discussion with regard to environmentally sensitive and/or energy-conscious roof design, I feel it is important to review from what perspective this opinion is being presented.

I am an architect, a roof consultant, the immediate past president of RCI, and a business owner in Barrington, IL. I am also a husband, a father, and a professional. Why is this important? Because I provide advice and recommendations to my clients, who have entrusted me to provide sound advice. As consultants we need current and truthful information, appropriate advice, and project assistance as well as relations building. As consultants our goals are to provide our clients with solutions that meet their needs as well as to keep lawyers at bay.

## WHY SHOULD ENERGY MATTER?

*The American School and University* magazine in December 2005 indicated that the total amount spent on energy by the nation's educational institutions, schools and colleges, in the year 2004-2005 was $13.8 billion. That seems like a great amount of money until a recent article in the *Wall Street Journal* indicated that $14.3 billion in bonuses was presented to Wall Street personnel in 2005. Obviously, there is an inequity at this point. Additionally, it is a subject of much conversation in industry periodicals and in the daily lexicon due to the high cost of oil and gas. The continued rise of energy costs has prompted a discussion with regard to energy and its relative importance to the roofing industry professional.

### Defining Energy

In order for a discussion regarding energy to be entertained, it's best to understand the terminology we are using. *Webster's New Collegiate Dictionary* defines energy as the "capacity of action or being active as well as the capacity of doing work." This is hardly a definition that you or I most likely would anticipate being used for energy. Only under **www.dictionary.com** did I find one that was close to my idea of energy; that was, "usable heat or power." Should we look at energy conservation, the definition of conservation is "the careful preservation of something and/or the planned management of a natural resource to prevent exploitation, destruction, or neglect." In pure definition terms, the conservation of energy is defined as "a principle in physics stating that the total energy of an isolated system (AC/furnace) remains constant regardless of the changes within the system (building)."

This is an important concept to understand: the total energy remains constant regardless of the changes within the building. A more simplistic retort would be that the output of the air conditioning or furnace system remains constant regardless of the use of interior computer systems, the number of people, lighting systems, inflow and outflow of materials and/or personnel. Thus, mitigating temperature changes through the roof is of great importance.

### Why does Energy Matter?

Things are changing. Climatic concerns and geographical modifications that normally happen in geological time are now happening during lifetime spans. Waters are rising, glaciers are melting and receding, polar ice caps are thinning, ice shelves are receding, and sea levels are rising. It is no longer a belief system, but is an observable, scientific fact that temperatures are warming. Whether it is due to global warming or millennium cyclical geological climatic change, things are changing.

Are we, the public and building owners, really concerned? Gas prices have spiked substantially in the last year, yet many homeowners still have their thermostats set in the 70s, resulting in heating bills of $700, $800, $900 per month for homes. Some trust in quick fixes. The Energy Star program relies on a single roof component (roof surface color) for energy conservation, which is an erroneous assumption. Lee Raymond, CEO of Exxon Mobil, probably said it best when he said, "Given the scale and long-term nature of the energy industry, there are no quick fixes and no short-term solutions."

Buildings represent more than one-third of the total U.S. energy consumption, account for two-thirds of all electricity use, are responsible for more atmospheric pollution than cars, and are responsible for 48% of $SO^2$, 23% of NO, and 35% of $CO^2$ emissions.

But help is on the way. The current Congress enacted a tax incentive rebate program. There is a federal tax incentive program if the roof system design exceeds

ASHRAE R-values by 50 percent of up to $.60/sq. ft. for roofing applications. It is being administered by the IRS through December 31, 2008. There is one defining fact on which this paper is based, and that is that energy costs will continue to rise. It matters because our children's children's future and the world they live in depend on how we act now.

## HISTORICAL PERSPECTIVE

The conservation and/or mitigation of energy or the influence of the geographical climate on buildings is not a new concept. Historically, indigenous buildings in various parts of the world have used architecture to mitigate the effects of exterior weather. Rising domes of mosques and thick walls to create wind and air flow through a building result in very comfortable temperatures, even in the hottest, 130F-degree days. Indigenous buildings in many parts of Europe and Asia have steep-sloped roofs that act as funnels to pull air through the buildings.

There are many parameters that affect building energy usage. In building design geometry, the shape of the building is a mitigating and important factor. What is the height of the building? What is the width of the building? Certainly a high rise has different geometric conditions than does a large big-box building. How is the building used? The location of the HVAC equipment is different in a high-rise than a low-rise building. Budgets differ. Placing of the HVAC system and how it is used have various effects on the building usage. These include:

- Gas boiler (flue loss).
- Electric boiler (both boiler systems have pipe loss).
- Gas-free heat (energy lost during gas burn).
- Electric reheat.
- Heat pumps.
- Hybrids.

This emphasizes the importance of working with the project HVAC engineer. Additionally, the type of energy heating/cooling system and system control will affect that energy. There are direct digital controls that have significantly reduced energy use. But what about the millions of existing facilities with aged systems and controls that will not be updated? With regard to HVAC controls, we have room-to-room control versus a centralized thermostat. How the owner will use them is an important factor as well as the thermal efficiency of the roofs, walls, and fenestration. Additionally, climatic factors, including sun angles, wind, temperature, snow, rain, cooling degree days, and heating degree days, as well as micro-climates, will affect energy usage on a building. So will the building's geographical location. It's all about location.

What have we learned in the past few years? That there is a factor that is not often considered and that often affects the outcome of many planned ideas: it's people. People use buildings in different ways. This is one of the concerns that the AIA has expressed in its concern about designing a LEED-certified building. The promise of potential results for a building that is "stick built" in the field, under often challenging conditions (not manufactured in a controlled environment), is a precarious promise to make. The Department of Energy (DOE) Building and Energy Book of August 2004 reports that 30 percent of the heat loss and only 7 percent of the cool load loss is through the roof. Consequently, the thermal efficiency of a roof (reducing heat loss) should be the guiding principle in roof system design in regards to energy conservation.

I would suggest defining the goal of the roof and walls. This could be through one of the following:

1) Mitigating the effects of solar radiation (induced heat load)
   a. All the time, versus
   b. Part of the time.
2) Leveling out peak demand, or
3) Capturing solar gain in winter in cold regions.

As can be seen, the possibilities and dynamics of energy conservation are very diverse and sometimes they are polar opposites.

The appropriate solution for the roof and walls can be a multifaceted process. First and foremost, the owner needs to be educated. He needs to be informed of the various opportunities and also that the solution might be multifaceted. He needs to understand the construction process, including sequencing; the consultant needs to understand roof use during construction and how it's going to be used following completion. We also need to realize the roof is composed of many elements that comprise a system, such as:

- Deck,
- Vapor retarders,
- Insulation,
- Cover board,
- Roof membrane,
- Fasteners,
- Adhesives,
- Ballast, and possibly
- Coating.

As one can see, the solution is not influenced by only one factor, such as roof reflectivity. Geographic sensitivity, maintenance, and long-term solution are also important. One factor of the roof system that appears to be underestimated is the benefit of the vapor or air barriers, which prevent the movement of air through the building envelope, reducing potential heat loss, condensation concerns, and increased energy costs. Additionally, roof system designers interested in saving energy should consider alternative and complementary solutions, such as photovoltaics, wind generators, garden roofs, gravel ballast, ballast pavers, and coatings.

As energy concerns have become issues, the roofing and building industries have responded with a number of products that will be part of the solution. Following is a short review of potential products:

***Photo 1 – Recent research by ORNL has found that ballasted systems, both paver and aggregate, provide the same level of energy conservation as do so-called "cool" roof systems.***

**Ballast**

The use of gravel ballast and pavers to resist wind uplift is well known. Recent research by Oak Ridge National Laboratories has concluded that the use of ballast can help save energy. The ballast is a heat sink. Thus, it mitigates any effects of solar radiation with regard to the temperature of the roof system and the surface below. Additionally, it pushes out any thermal gain of the roof to a later period, possibly missing peak demand (see *Photo 1*). We all know this intuitively: shaded areas are cooler than areas directly exposed to solar radiation. It appears promising that the use of ballast as an alternative for cool roofing systems in the Title 24 program and in the Energy Star program will be accepted in the near future.

**Coatings**

In addition to extending service life, coatings may provide a sustainable benefit to the environment by delaying landfill accumulation and roof replacement. They also may help create a better work environment and help reduce peak energy demands.

**White-surfaced membranes**

In response to code mandates, city ordinances, and Energy Star, most low-slope roofing membrane manufacturers now produce a product that offers a relatively high level of initial reflectivity and/or emissivity. Designers are cautioned about promising high potential energy savings as membrane surfaces soil over time. Additionally, designers should consider the potential effects of increased solar radiation on adjacent structures.

**Thermal insulations**

The thermal insulation industry has been hard pressed and mandated over the past decade to become environmentally responsible. Its formulation changes now appear to be in place. As such thermal insulation products have become quite dimensionally stable. Field observations found that the product holds substantial R-value and can be counted on for long-term performance. It appears that the highest potential savings is when thermal insulation is incorporated into the roof system (see *Photo 2*). The Department of Energy reports that 30% of the heat loss is through the roof. Double layers of staggered insulation are not only a recommendation but this author would consider a mandate. This author's own recent investigations have revealed tremendous condensation occurring below mechanically fastened, white, single plies used in concert with single-layer insulation.

**Steep-slope roofing products**

The various asphalt shingle manufacturers have developed cool shingles. The metal industry has also developed cool metal paint coatings that are now available with greater reflectivity and with higher emissivities than normal, prefinished products. This is an encouraging response from those industries, in that they provide opportunities for designers for their use. Additionally, the

***Photo 2 – The use of high levels of thermal insulation is a sustainable methodology in the conservation of energy.***

Clay Tile Association has recently completed research that has shown improved energy savings with air space below the tile.

**Innovative materials**

Recent research at Oak Ridge National Laboratories (ORNL), under the auspices of André Desjarlais, has developed several unique materials that may prove to be beneficial for energy savings in roofing materials.

- **Cool colors:** Material finishes that are dark in color, but have high reflectance value.
- **Thermocromic materials:** Materials that change color with temperature changes. The material has proven to be highly durable and can be laminated to single-ply membranes.
- **Phase change materials:** When added to traditional lightweight insulations such as blown cellulose and fiberglass loose fill, they add the characteristics of a massive material such as concrete by absorbing and storing large quantities of energy.

A DESIGNER?S RESPONSIBILITIES

Having a goal of designing an environmentally sensitive roof or providing one that is energy conscious is mutually inclusive. One cannot design a roof system for the short term – no matter how much insulation is incorporated in the building – without experiencing one that is not environmentally sensitive with regard to the amount of landfill, labor, and energy introduced into the new roofing system. Thus, an over-riding factor for the design of environmentally sensitive and energy-conscious roofs is design for the long term. High-quality, long-term performing roof systems are the essence of sustainability, and therefore, an inalienable requirement of any roof system desired to be environmentally sensitive and energy conscious.

Following are two case studies of actual projects that have aspired to be environmentally sensitive and energy efficient.

CASE STUDY I — NILES WEST HIGH SCHOOL FIELDHOUSE, SKOKIE, ILLINOIS; ROOFING REMOVAL AND REPLACEMENT

The large field house, a 2-story complex encompassing 75,000 sq. ft., is part of a large, two-school campus. The existing built-up roof had served well for a number of years and was in need of replacement. The field house interior was a multi-use facility kept at 72°F, winter and summer. This required great heat and cooling loads. The school district's goal was to look to the future and design a roof system that had not only long-term performance, but also provided an optimal energy-saving roof system. I also aspired to accommodate as many as possible of the sustainable roofing tenets as developed by the CIB-RILEM joint committee on sustainable low-slope roofing systems.

The original roof system was deemed to be deteriorated; as such, its removal was required. The roof structure had some camber to the steel joists; therefore, tapered insulation was installed to achieve positive drainage. The insulation specified was tapered polyisocyanurate roof insulation with an R equal of 6 per inch overlaid with a 1-inch wood fiberboard. The design incorporated polyisocyanurate insulation due

CASE STUDY I PROJECT FACTS

| | |
|---|---|
| **Size:** | 450 square feet |
| **Contractor:** | Bennett & Brosseau Roofing, Inc. |
| **Roof System Manufacturer:** | Soprema 3-ply, granule-surfaced, modified bitumen. |
| **Final Construction Cost:** | $550,000.00 |
| **Construction length:** | 8 weeks |
| **Warranty:** | 20 years (NDL) |
| **Thermal Value:** | R-value average, 65; low, 30; high, 100 |

to its ease of installation in hot asphalt, its relatively high thermal value, and its performance history in the Chicago area. A thermal value of R30 at the roof drains was designed, and then tapered to approximately 17 inches or an R of just over 100. A layer of 1-inch-high density wood-fiber board was installed in hot asphalt, followed by a modified base sheet, modified bitumen smooth-surfaced interply, and granule-surfaced cap sheet. All parapet perimeter walls approximately 3 to 4 feet in height were covered in pre-finished, aluminum-set metal siding. The roof system was designed to achieve a 30-year life.

The contractor was informed at the preconstruction meeting and bidding of the client's goals and intentions. The contractor worked well with the district personnel and this author to achieve the desired results. Reports from the school district have indicated that even with the huge spike in energy costs that have almost tripled since the time of the roof system installation, the energy costs for the roof are less than they were previous to roof installation. Winter heating costs have been lowered substantially, user comfort levels have improved, and an improved environment has resulted. A cost analysis revealed that the cost savings to date have almost equaled the cost of all the insulation for the project.

CASE STUDY II — ILLINOIS DEPARTMENT OF TRANSPORTATION, DIST. 1, SCHAUMBURG, ILLINOIS; ROOFING REMOVAL AND REPLACEMENT

The Illinois Department of Transportation (IDOT) District One Facility is the brain trust of the Chicago land transportation system. When all other facilities shut down due to inclement weather, the IDOT facility is bristling with activity in order to monitor and safeguard the vital transportation lines. Thus, when a new roof system was required, its design was critical to the function of the facility in all types of weather. Consequently, the building was deemed an essential facility and thus the roof was also considered essential, meaning when all other roofs may be damaged or blown off, this roof needed to be in place and performing. Long-term, high-end performance and optimal thermal resistance were required by the IDOT.

Due diligence and field verification revealed that the existing roof system was a four-ply, built-up roof over phenolic insulation on a metal roof deck. 10-ft by 10-ft sections of the roof and insulation were removed in order to ascertain the condition of the structurally sloped metal roof deck. While showing surface corrosion, the structural integrity was deemed acceptable and thus surface prep and painting were specified. The building user indicated that heating the building with electricity had resulted in exceedingly high electric bills and that they would like to see those reduced while providing increased employee comfort. Other building components that impinge upon the roof are a pre-cast concrete parapet, interior roof drains, screen wall supports, mechanical penthouse walls, and a computer room cooling tower that could not be shut down under any circumstance.

After a review of potential roof system solutions, a 90-mil, fully adhered EPDM roof system was selected. The EPDM membrane was selected in part because of its long-term performance capability and potential. The roof was designed to achieve FM 1 120 requirements and to obtain a 30-year, full-system warranty with hail- and puncture-resistance

CASE STUDY II PROJECT FACTS

| | |
|---|---|
| **Size:** | 305 square feet |
| **Contractor:** | All American Exterior Solutions |
| **Roof System Manufacturer:** | Firestone Building Products |
| **Final Construction Cost:** | $405,000.00 |
| **Construction length:** | 7 weeks |
| **Warranty:** | 30-year, full-system warranty; 72-mph hail and puncture coverage |
| **Thermal Value:** | R Value (full system), 33 |

***Photo 3 – Illinois Department of Transportation District I building; R-38, 30-year warranty.***

coverage.

In order to accommodate the painting of the metal roof deck and to provide an air and vapor barrier, a vapor retarder composed of 1/2-in fiberglass reinforced gypsum board mechanically fastened and with a 45-mil EPDM membrane fully adhered was installed. The use of 45-mil EPDM as a vapor retarder sheet allowed the contractor to not only enclose large areas quickly, but to also render watertight flashing conditions quickly with the self-adhering flashing and components.

Following the installation of the vapor retarder, two layers of 2.5-in, 25 psi polyisocyanurate were placed, overlaid with a layer of 1/2-in fiberglass-faced gypsum board, mechanically fastened to meet FM 1-120 requirements: 32 fasteners in the corners of the roof, 28 at the perimeter, and 18 in the field of the roof. The 90-mil EPDM was fully adhered to the cover board and the lap seams bonded with 6-in seam tape and then overlaid with a 6-in piece of self-adhering, semi-cured EPDM cover strip, and the edges sealed with lap sealant (see *Photo 3*).

At the parapet walls, the field sheets of the 90-mil EPDM were carried up and over the top of the precast and fully adhered. Tall, steel penetrations were sealed with pourable sealer and then covered with metal raincaps. The mechanical penthouse base flashing was achieved by loosening up the siding to allow for the extension of EPDM flashing and metal counterflashing up behind the panels. Prefinished steel copings with drive-cleated vertical and horizontal joints, which aligned with the exterior façade precast, concrete joints, were installed at the perimeter roof edge.

Tim Schulze of All American Exterior Solutions, project superintendent, praised this project: “In 34 years of roofing experience, the roof system designed for IDOT District 1 is one of the finest roof systems I've ever been involved with.”

Kevin Schlenger, business manager of the IDOT facility, called his new roof, “A joy! After years of problems, leaks, noise, and concerns with corrosion, it is a great relief and satisfaction to have received a roof system that will perform for us for the next 30 years and beyond.”

## CONCLUSIONS

When all is said is done, we don’t really have all the answers. Buildings are unique; we are still learning how they respond. It is best to think about a holistic approach to energy savings.

- Do not sell a project on a single attribute.
- Give consideration to multiple alternatives.
- High-performing thermal insulation performs 24 hours per day, seven days per week, 52 weeks a year, and for years in the future.
- Consider unique solutions, such as the use of ballast, with its self-cleaning, long-term performance characteristics.
- Realize that energy to be saved is not only that which is counted in kilowatt hours. Human effect, lost productivity, repairs, etc., are all lost energy components
- Think long-term.

- Proceed cautiously, but proceed.
- Learn from successes and miscues. After failing 1000 times, Thomas Edison proclaimed, "I have found 1,000 solutions that do not work!"
- Work together with those in our industry as well as other design professionals.
- Continue to invent and think of the future.
- Be open-minded.
- Be honest.
- Realize there are no set answers – only opportunities that exist for the future.