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Journal

The Building Envelope: Energy Efficiency and Economics

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According to the U.S. Environmental Protection Agency (EPA), the construction and operation of buildings is responsible for nearly half of America's greenhouse gas emissions. In comparison, all forms of transportation combined—including airplanes, trucks, buses, and cars—account for just a quarter of total emissions. Because so much of the country's building stock was constructed when fuel was cheap and plentiful, little regard was paid to designing energy-saving enclosures.

As the barrier between the indoor and outdoor environments, the building envelope is critical to energy performance.

As these structures age, we are faced with a choice: rehabilitate and upgrade the inefficient buildings, or replace them.

With landmark and historic structures, the importance of preserving the existing building is clear. But what about buildings that are neither efficient nor architecturally significant? Replacing an old building with a new one uses energy. That energy takes many, many years to recover through improved performance—if at all. A better approach, then, is to improve the energy profile of the buildings we already have.

To cut back on energy consumption, federal, state, and local authorities have adopted increasingly rigorous standards for building performance. These regulations, along with tax incentives for improved energy management, have led to an upsurge in energy efficiency retrofits for existing structures. Before investing in major capital improvements to heating and cooling systems, however, consider making simple, less costly upgrades to the building enclosure. A sound exterior envelope acts as a thermal shield, reducing demand on HVAC equipment, improving indoor comfort, and extending the lifespan of building components.

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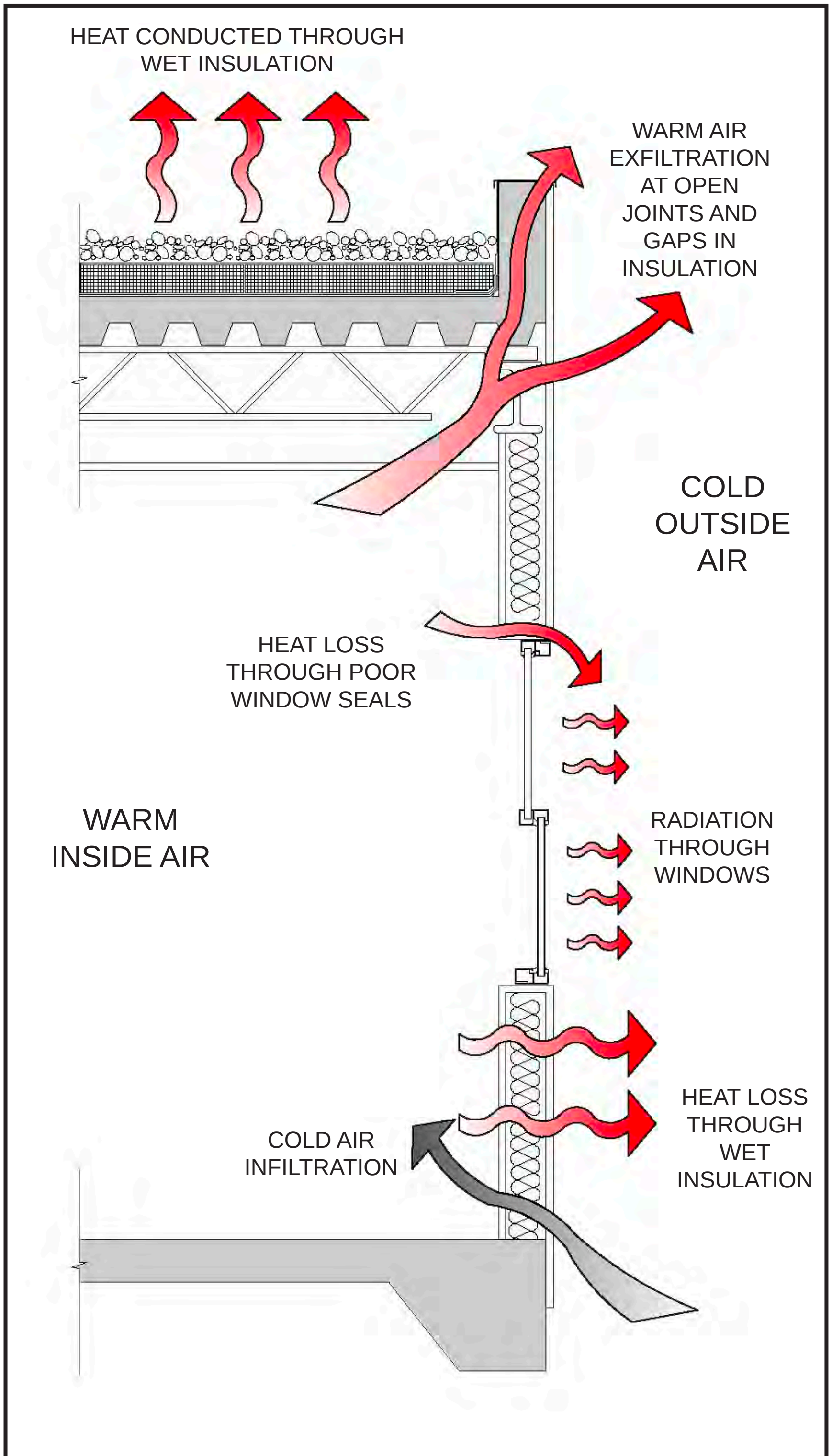


Heat Loss In Winter

Roofs

More often than not, faulty roofs are behind performance-compromising conditions, from leaks to heat loss. As the portion of the building hit hardest by acid rain, UV light, snow, ice, foot traffic, and chemical pollutants, the roof tends to degrade faster than do other portions of the building exterior.

Leaks Are More than Dripping Water

They're also a source of heat loss. Wet roofing materials lose their insulating properties, causing the roof to act as a conductor, rather than an insulator. Heat rises, so without a thermal barrier at the roof level, heat travels up and out of the building.

Limit potential points of water entry by minimizing the number of penetrations through the waterproofing membrane. Don't neglect flashing details; the roof perimeter, along with any intersections between the roof membrane and parapet walls, penthouses, or other roof levels, is an easy target for moisture if not correctly sealed and protected by the flashings.

Is Your Insulation Really Insulating?

Insulation secured with fasteners may not have you covered as well as you thought. For steel decks, the metal acts as a thermal bridge, conducting heat through the insulation. A safeguard would be a multi-layer system, with chemically adhered insulation over mechanically fastened boards. Even with fully adhered insulation, if sections are not fully abutted, it is possible for air to pass through the gaps between boards. Staggered joints cover any space between sections.

Not Every System Is Right for Every Building

Cool roofs, green roofs, solar roofs… overwhelmed with all the options? You're not alone. But the kind of

A design professional can assess your roof's insulating properties.

Cool roofs reflect heat, cutting energy costs and normalizing urban temperatures. Pictured here is a modified bitumen roof (MBR) with a reflective capsheet.

building you have—as well as the roof that's already in place—might make choosing an energy-efficient roofing system easier than you thought.

Green roofs, also known as ***vegetated roofs*** or ***verdant roofs***, incorporate plants into the roof assembly. They add insulating value, reduce storm water runoff, cool the building interior and the surrounding area, provide habitat for birds and insects, and look great. But they can also be heavy. While this might be an excellent sustainable retrofit for some buildings, it could be structurally disastrous for others. Before you commit, a design professional should evaluate the load-bearing capacity of the building and determine if structural modifications would be necessary to support plantings, growing and drainage media, and related components.

Cool roofs sound appealing. But what is a cool roof, anyway? In its simplest form, a cool roof is just a roof that's light-colored. So what's the hype? Darker colors absorb heat. A white or reflective roof can cut cooling costs by reflecting heat away from the building. In urban areas, where there is little greenery and lots of heat-absorbing concrete and asphalt, cool roofs help to cut down on mass heat retention known as the ***"heat island effect."*** When selecting a product, consider material shortcomings, such as potential for split seams or non-uniform coverage; for some systems, the risk of premature failure may outweigh the benefit of increased reflectance.

Solar roofs use photovoltaic cells to convert sunlight into usable energy. Solar panels are not a roofing material, however; like any rooftop equipment, they can cause leaks if installed incorrectly. Unless your roof is in good shape, the expense of repairing water damage could cancel out any cost savings from the solar power.

The ***Energy Star*** program, created by the U.S. Environmental Protection Agency and the U.S. Department of Energy, can help you and your designer evaluate the options, with tools to measure performance, compare products, and track savings. All of the above systems can earn ***Leadership in Energy and Environmental Design (LEED)*** points for a retrofit project. The important thing is finding which one is right for your building.

Facades

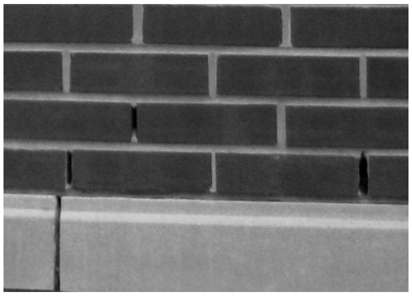
A facility manager replaces outdated cooling equipment to improve energy performance, then adds a solar film to the windows as an inexpensive efficiency upgrade. Smart thinking, right? Well, almost. These are both good ideas—just in the wrong order.

The facility manager bought the chiller system to accommodate existing cooling demands, and then reduced those demands by adding the window coating. Not only did the facility manager overspend, the now-outsized chiller wastes energy, costs more to operate, and decreases indoor comfort.

The lesson: before making big-ticket improvements to mechanical systems, ensure that your facade provides a good thermal barrier.

Seal It Up…

Cracked, loose, or missing mortar joints and deteriorated sealant joints allow moisture to enter the wall. Because water conducts heat, wet walls lose their insulating value and make mechanical equipment work harder to keep up with heat transfer. The same holds true for glass curtain walls and windows, where deteriorated gaskets



Repair cracks, but leave weep holes open, so water can make a quick exit.

and seals not only let in water, they create drafts and temperature fluctuations at the building periphery.

...But Let It Out

Not all holes in the building exterior are bad. Often, well-meaning maintenance personnel make the mistake of sealing over ***weep holes***, small voids in exterior walls that drain water from within the wall cavity. When dry, these cavities provide insulating value. But if water becomes trapped, the thermal conductivity of the wall increases and heat escapes. The constant presence of moisture also leads to other problems, from mold growth to building component degradation.

Condensation doesn't just cloud the view, it points to poor thermal performance.

Don't Let Heating Dollars Fly Out the Window

To avoid overspending, have an architect or engineer evaluate your existing windows and recommend appropriate options.

Problem areas to watch for:

- ***Broken gaskets and seals.*** Without a proper seal, windows permit water and air to pass through at the perimeter. Condensation between panes usually points to a broken thermal seal, which means that the insulating capacity of the window has been compromised.
- ***Failed thermal breaks.*** Cold / hot spots or condensation on window frames could point to damaged or missing insulator material.
- ***Glare.*** Daylighting is important to minimizing energy consumption, but when it comes to sunlight, more isn't necessarily better. Glare diminishes visibility, particularly at computer workstations.
- ***Solar heat gain.*** Direct sunlight can also cause overheating. Designers use the solar heat gain coefficient (SHGC), a measure of transmitted solar energy, to optimize windows' impact on indoor temperature.
- ***Drafts.*** Heat fluctuations not only mean that HVAC systems have to work harder to stabilize temperature, the variable conditions can make the building periphery uncomfortable.

Strategies for improving window performance range from taking aim with a caulking gun to installing energy efficient replacements. To maximize natural lighting, reduce heating and cooling costs, and control the undesirable effects of overheating and glare, look for windows with some or all of these properties:

Insulated glazing units (IGUs), also called double-glazed or triple-glazed windows, improve thermal performance with the insertion of a gas or vacuum space between panes of glass.

Low-emissivity (low-E) glass reflects infrared radiation, and so reduces heat transfer without affecting natural lighting.

Solar films or tints keep rooms cooler in bright sunlight and cut down on glare. Shaded glass that responds to an applied electrical current offers variable opacity control.

Thermal breaks, which are plastic or rubber separator materials, minimize heat conduction across inner and outer window frames.

Technologies are constantly evolving. Work with your design professional to assess your energy goals and building condition to maximize window efficiency and minimize costs.

Failed sealant provides a pathway for heat, air, and moisture transfer.

Are Your Doors Leaving You Wide Open?

In terms of square footage, windows outrank doors as the facade element most critical to energy conservation. Acres of leaky single-pane windows are much more of an energy concern than are a half dozen inefficient exterior doors. Still, a building enclosure is only as good as its weakest element. If doors are drafty, an entrance lobby can feel unpleasantly hot or cold, and HVAC systems will run overtime. If the insulating value of your doors is low, it might be worthwhile to replace them. As with windows, doors need regular upkeep to maintain their rated level of thermal protection, including periodic sealant replacement, hardware maintenance, and frame and threshold repairs.

What Is "Building Envelope Commissioning"?

"Commissioning" is a term that's being bandied about in the industry, but it's really just a new way of expressing an old idea: make sure everything works together.

A changing industry. Time was, buildings were made of a limited range of materials and built by master craftsmen. With the expanding array of building materials and shifting styles of contemporary construction, it's difficult for an installer to have prolonged experience with any one type of system. Combine the daunting number of material options with decreased training for construction teams, and you have a recipe for trouble.

Commissioning often includes performance testing, such as water intrusion tests, to see that assemblies react as designed.

A demand for oversight. Building envelope commissioning addresses this problem by posting a building enclosure expert, usually an architect or engineer, at the job site. To assure the continuity of interdependent systems, he or she oversees the work of the diverse contractors, designers, and specialists responsible for the building envelope.

An efficient building, built efficiently. From an energy conservation perspective, commissioning is important on a number of levels. First, it avoids wasted time and resources by managing installation sequencing and construction scheduling. Second, it protects against premature component failure due to incompatible materials or differential movement. Finally, it optimizes building envelope performance by identifying and correcting energy leaks at building intersections.

A holistic approach to energy upgrades enables the building enclosure to function as an integrated system, rather than as a collection of disjointed parts. ■

Below-grade Elements

An un-insulated basement might be costing more than you'd expect, especially if mechanical equipment is housed below grade. In winter, the average temperature of earth, which is the same as that inside most un-insulated basements, is about 55°F. As heat moves through exposed ducts, it raises the temperature of the surrounding air and escapes through the walls. Adding insulation to ducts, basement walls, and ceilings can therefore reduce heat loss. As further incentive, protecting ductwork and mechanical systems helps to extend their serviceable life by reducing on/off cycling and heating loads through improved efficiency.

Quantifying Heat Loss

Visual observation provides a general picture of building envelope condition, but there are many things you can't see. Deficiencies beneath the surface can be detected through ***infrared thermographic testing.***

Infrared analysis can locate thermal anomalies caused by, for example, missing insulation, air or moisture infiltration, or "hot spots" where mechanical or electrical equipment is malfunctioning. Thermography is non-invasive and can be performed during normal building operation. Using temperature scanners, the test generates pictorial representations of a building component's thermal profile. Correct analysis of this data can reveal problems not otherwise identifiable on an existing, occupied structure.

However, accurate interpretation of thermal images demands understanding of building envelope composition. Certain types of construction tend to dissipate heat, leading to false negative readings, whereas others reflect heat and generate false positives.

In the right hands, thermographic testing can be a useful diagnostic tool. When incorporated into a comprehensive condition assessment, infrared analysis can save resources by prioritizing renovation efforts and avoiding unnecessary repairs.

Warranty Considerations

Before putting an energy management plan into effect, check warranties. Some modifications, while well-intentioned and, even, performance-enhancing, might void the terms of the warranty. For example, most roof membrane manufacturers offer warranty protection but include stipulations about post-installation alterations. The same holds true for windows, doors, waterproofing materials, and anything else with a written guarantee. Be on the lookout, too, for how components interact; don't attempt to reduce roof penetrations, for instance, by re-directing exhaust pipes without first checking with the

Poorly performing doors make HVAC systems work overtime to stabilize temperature.

equipment manufacturer. You may find yourself out of luck if the equipment fails due to your actions.

Municipal, State, and Federal Regulations

Green Government

A number of state and federal agencies have adopted "green" policies for retrofits and rehabilitations. A sampling:

- In Washington DC, *The Architect of the Capitol (AOC)*, steward of the U.S. Capitol complex, initiated "Power to Save," which encourages energy savings through operational improvements. "Green the Capitol" sets conservation goals that include building enclosure performance.
- In New York City, the *School Construction Authority (SCA)*, which manages the city's 1,600 public schools, launched the "NYC Green Schools Guide and Rating System" to quantify energy and resource conservation.
- At the federal level, the *General Services Administration (GSA)*, responsible for some 8,600 federally-owned facilities, applies mandated efficiency and sustainability guidelines to new construction and major renovations.

The idea behind these and other initiatives is to lead by example. By championing energy efficiency at government-owned properties, legislators hope to encourage broader adoption of similar carbon-reduction measures.

Tax Incentives

For energy efficiency upgrades that reduce heating and cooling loads by at least 50%, the IRS offers a tax deduction of up to $1.80/sf. Partial deductions can be taken for measures that specifically target the building envelope. In addition, some states and municipalities have their own programs to help offset the initial expense of performance upgrades.

Code Requirements

Because energy codes are constantly changing, you may not be able to simply call in a roofer to install the same system you're tearing off, nor replace other building components in kind. A design professional should evaluate applicable requirements as part of initial cost projections, and design appropriately.

Calculating Energy Savings

It would be great to replace every roof in a large metropolitan area with an energy-efficient cool or green roof, and every window with a high-performance one. Wouldn't it?

Not exactly. Tearing off existing components uses energy, and so does manufacturing and installing new ones. Before making the decision to replace an assembly, have a design professional evaluate your system's condition, as well as your energy goals. A return-on-investment evaluation can tell you how quickly, if at all, you could recoup the cost of replacement through energy savings and net gain in value.

LEED or Energy Star recognition for efficiency improvements can raise property values, improve tenant retention, and generate a positive public image. If roofs or windows are at the end of their lifespan, it makes sense to install new, energy-efficient materials. But replacement of a serviceable component for the sake of energy savings alone may not be worth it.

All building types can benefit from better energy management. The real dollar value of energy efficiency measures lies in knowing which improvements are appropriate—or, even, necessary—for your building.

Realistic Goals for Existing Buildings

While it's important that new structures be designed to minimize their carbon footprint, the real greening of America's cities will come with improving the energy efficiency of the buildings that have already been built.

As the building's thermal barrier, the exterior envelope should be the first step in a multi-component energy management strategy. An architect or engineer experienced in building enclosure design can help you determine where best to focus your efforts, phasing efficiency upgrades to build on one another over time. To realize the

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representative projects

Energy Efficiency

Hoffmann Architects has spent over 30 years developing building enclosure solutions to optimize energy efficiency. From heat loss evaluation to rehabilitation design, the firm's architects and engineers have the experience to restore building integrity and improve performance. Hoffmann Architects has enhanced the energy profile of a number of buildings, including:

Packer Memorial Church
Lehigh University
Bethlehem, Pennsylvania
Master plan to restore and weatherproof the historic structure

Telcordia Technologies Headquarters
Piscataway, New Jersey
Window energy efficiency study, including building energy modeling, tax incentive research, and return-on-cost analysis

Schering-Plough Corporation in Summit, NJ. *Facade reconstruction to improve energy profile and aesthetics.* New Jersey Golden Trowel Award, Special Recognition.

Yale-New Haven Hospital, 55 Park Street Laboratory in New Haven, CT. *New construction consultation and feasibility assessment for curtain wall, roofing, and foundation waterproofing.*

Defense Intelligence Agency Center
Bolling Air Force Base
Washington, District of Columbia
Evaluation and design for waterproofing, insulation, and sealants

Paramount Building
New York, New York
Water infiltration investigation for below-grade pedestrian tunnel

Arts and Industries Building
Smithsonian Institution
Washington, District of Columbia
Roof investigation and repairs to address recurrent leaks

Crowne Plaza Hotel Times Square
New York, New York
Facade and roof design consultation, addressing air and moisture leaks

Mastercard Headquarters
Purchase, New York
Facade and entry plaza rehabilitation to arrest water penetration and deterioration

Aramark Tower
Philadelphia, Pennsylvania
Masonry and window repair design

Kings County Hospital Center
Brooklyn, New York
Facade repairs and roof replacement to improve weather protection at the 175-year-old facility

Paul Rudolph Hall
(Formerly Art + Architecture Building)
Yale University
New Haven, Connecticut
Renovation, including new energy efficient windows, doors, and "cool" roofs. International Concrete Repair Institute Award, and AIA New York State and AIA Connecticut Design Awards

Capital Community College
Hartford, Connecticut
Window, roof, and facade retrofit for historic retail building, now part of the downtown campus

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A building envelope energy plan coordinates improvements, such as sealant replacement, stone panel repairs, and window upgrades, to optimize component integration and efficiency.

maximum benefit from your investment, opt for retrofits that integrate multiple areas and work in concert to address energy leaks.

Building enclosure improvements need not break the bank. Many simple actions to protect against heat loss, such as re-sealing joints or repairing window frames, do a lot without costing a lot. Attention to details, junctions, and system dynamics can make the difference between efforts that actually improve building performance, and those that waste more energy than they save.

Lower heating and cooling costs, longer building component lifespan, improved building integrity, better occupant comfort, and increased property value are some of the advantages of well-designed building envelope upgrades. The trick is to set energy objectives that are attainable for the building you have.

Related topics are covered in other JOURNAL issues, which can be downloaded at www.hoffarch.com.

JOURNAL is a publication of Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors. The firm's work includes investigative and rehabilitative architecture and engineering services for the analysis and resolution of problems within roofs, facades, glazing, and structural systems of existing buildings, plazas, terraces and parking garages.

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