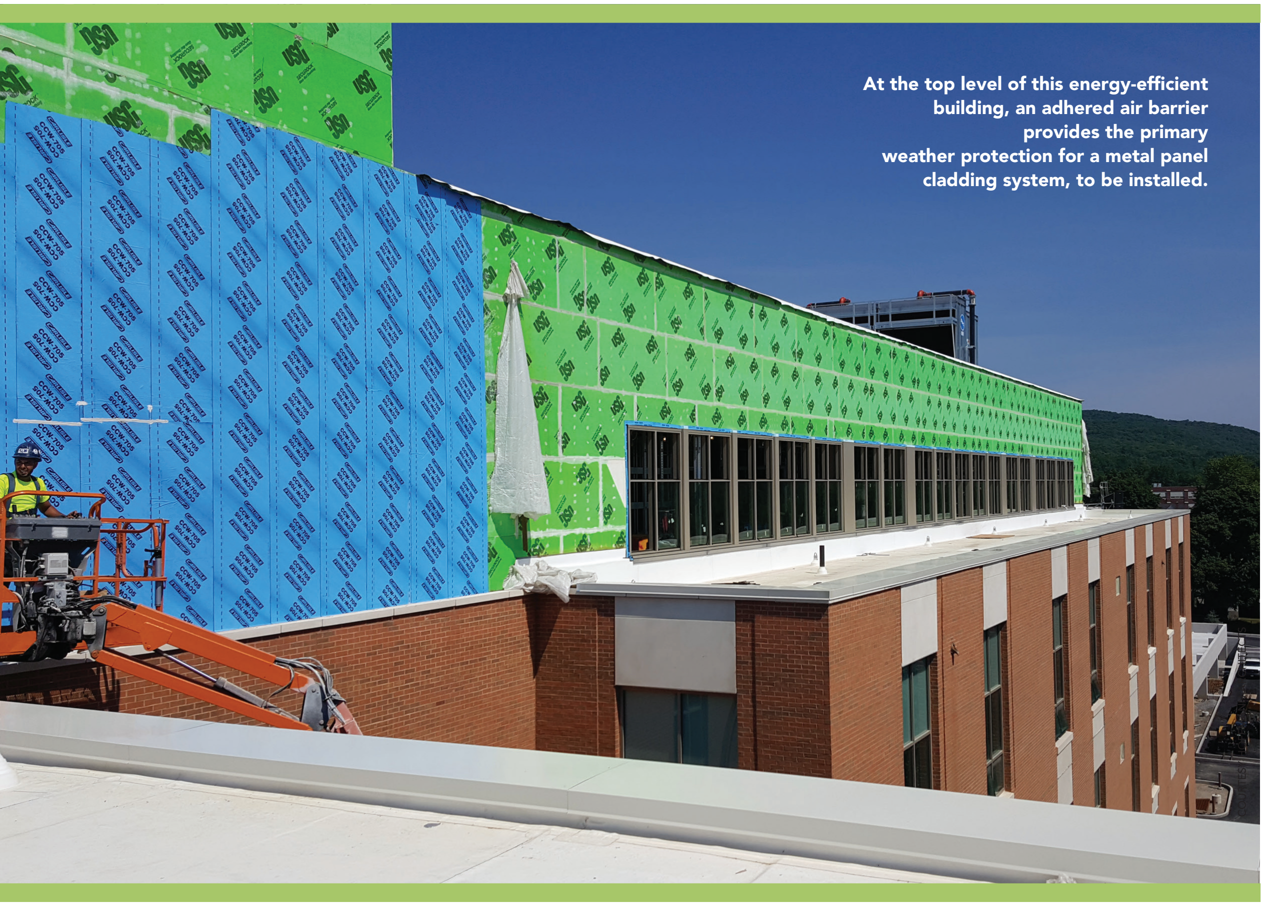
MEETING THE DEMAND FOR HIGH-EFFICIENCY FAÇADES



At the top level of this energy-efficient building, an adhered air barrier provides the primary weather protection for a metal panel cladding system, to be installed.

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LEARNING OBJECTIVES

After reading this article, you should be able to:

- **+ BALANCE** energy use goals with practical considerations, such as constructability, performance, and product availability.
- **+ APPLY** principles of thermodynamics and energy transfer to the appropriate design of energy-efficient building enclosures.
- **+ DETERMINE** energy code compliance by demonstrating thermal efficiency through calculations or energy modeling.
- **+ ACCOUNT** for sites of thermal bridging by incorporating high-efficiency detailing that addresses sources of energy loss and insulates against heat transfer.

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On February 24, 2017, *The New York Times* published an article regarding the eventual decommissioning of the Indian Point Nuclear Power Plant, just north of New York City, which the governor intends to close by 2021. A report on the implications of the plant shutdown found that the need to find new sources of energy could be mitigated if New York followed the lead of Massachusetts and Rhode Island in providing incentives to drive down energy consumption, particularly through improved efficiency in building systems.

Energy codes mandating more efficient use of buildings—and, by extension, of building enclosures—are already being adopted by many states as a logical step in the reduction of energy consumption. On a national scale, the impetus to improve building energy performance is manifest in the latest and most far-reaching model energy code from the International Code Council, the 2015 International Energy Conservation Code (IECC). Compared with energy standards of just a few years earlier, the 2015 IECC sets a high benchmark for energy performance.

In 2010, the required insulative value for a new roof on an existing commercial building was R-20, per the IECC. Today, it's R-30, a 50% increase. Replacement fixed windows in 2010 needed to perform at R-1.82. Now, that number is R-2.38, 30% greater.

This trend toward increasingly stringent energy performance standards is likely to continue. Several states and municipalities, including New York, New Jersey, and Maryland, were early adopters of the 2015 IECC. Others have already passed legislation to roll out the new, more demanding energy standards over the coming months.

For design professionals, designing and detailing building enclosures to meet these strict performance benchmarks demands knowledge not only of building envelope systems, but also of the requirements and objectives of the energy code, the fundamentals of thermodynamics and energy transfer, and high-efficiency enclosure detailing.

For property owners and facility managers, understanding the code requirements for energy-efficient design, the science behind those standards, and the process involved in achieving energy performance goals is critical to an informed and judicious approach to planning construction that meets stringent energy mandates.

When and why to exceed the requirements of the code, and how to balance energy-use goals with practical considerations such as constructability, performance limitations, product availability, logistics, and cost, are further considerations. In some cases, it makes sense to go beyond the published standards and achieve forward-thinking energy performance that looks ahead to energy-efficiency trends. In other situations, the net energy reduction for a given upgrade may not be sufficient to justify the costs. Primarily, these considerations pertain to new construction, but some of the cost-benefit analysis could just as well apply to retrofit decisions for existing buildings.

UNDERSTANDING THE CURRENT ENERGY CONSERVATION CODE

First issued in 2000, the IECC is a model code, which means that it is not, in itself, a regulation or law, but rather a set of directives that may be adopted by state or local jurisdictions, either as is or with location-specific modifications. Every three years, a new version is released, with guidelines that up the ante on energy performance. The current edition, published in 2015, incorporates ANSI/ASHRAE/IES Standard 90.1-2013 – Energy Standard for Buildings Except Low-Rise Residential Buildings (ASHRAE 90.1). A reference standard, ASHRAE 90.1 provides minimum requirements for energy-efficient building design and establishes criteria by which to determine compliance.

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Eventually, high-efficiency detailing that cuts energy use will likely be mandated by code.

There are three basic steps to meeting energy code requirements. First, identify which version of the IECC applies to the project. Second, to establish performance criteria, determine the correct building climate zone. Finally, choose the correct path to energy code compliance dictated by the characteristics and composition of the building dictate.

STEP 1: Know Your Code

The 2015 IECC is the newest version of the code and therefore a logical reference point for this discussion. However, it is important to know which version of the code is in effect for the jurisdiction in which a building is located. If there is no legal reason to comply with a newer, more stringent version of the IECC, then decisions about the energy performance of a building assembly become about balancing practical concerns with performance goals, rather than about meeting immutable efficiency requirements.

STEP 2: Know Your Climate Zone

To design an energy-efficient building enclosure, it is essential to identify the type of climate in which the building is located. The basic distinction is between heating climates and cooling climates.

ASHRAE 90.1 uses the concept of heating degree days (HDD) and cooling degree days (CDD) to characterize these two climate types. Degree days are calculated as the difference between the mean temperature and a given base temperature, in this case 65°F for HDD and 50°F for CDD. Heating days have an average temperature below 65°F, while cooling days are warmer than 50°F.

HDD and CDD are aggregated over the course of a year, to specify the nominal heating or cooling load and to estimate energy consumption. If annual HDD exceeds CDD, the building is in a heating climate, or one that requires the use of heat more often than air conditioning. If the opposite is true, then the building is in a cooling climate.

While heating and cooling are the chief climate identifiers, there are many distinctions beyond these two broad categories. For the continental United States, ASHRAE 90.1 identifies no fewer than seven climate zones. From a practical design standpoint, though, there are four main climate types to consider:

- Moist heating climate
- Dry heating climate
- Moist cooling climate
- Dry cooling climate

For each of these climate types, the IECC and ASHRAE 90.1 provide prescriptive requirements for energy efficiency of the building envelope. Before applying these values, however, you must first quantify certain key characteristics of the enclosure design to establish whether the prescriptive path is appropriate for the building.

STEP 3: Know Your Building

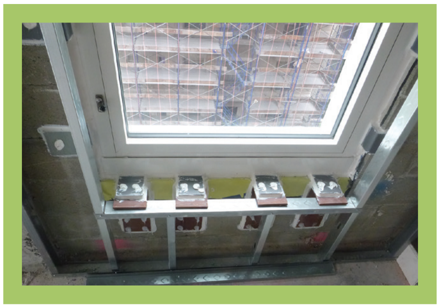
Whether the prescriptive values set by ASHRAE and the IECC can be used to design an energy-efficient, code-compliant building envelope depends primarily on the percentage of glass in the façade.

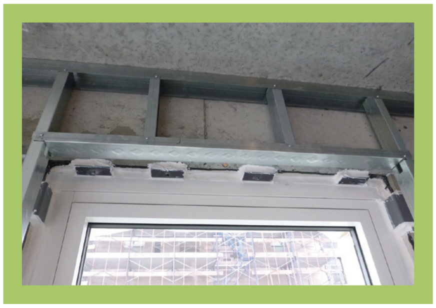
Prescriptive Path

The 2015 IECC states that, to follow the simpler, prescriptive path to energy code compliance, vertical fenestration area must not exceed 30% of the above-grade wall area. That figure includes windows, window walls, and glass doors, but not opaque doors and spandrel panels. For most climate zones, the proportion of glazing may be increased to 40% if code-compliant, daylight-responsive shade controls are incorporated into the design.

When considering the curtain wall buildings that dominated new construction in the second half of the 20th century, it may seem excessively restrictive to limit window area so severely. However, most of the energy loss across a building enclosure is through the fenestration. The code recognizes that glazed assemblies are inefficient when compared with the opaque portions of the building envelope. Furthermore, additional glazing is often unnecessary to achieve the desired indoor environment.

As a result, the IECC and ASHRAE 90.1 (and, by extension, the jurisdictions that adopt them) are stipulating a reduction in the proportion of fenestration in building façades as a reliable way to improve energy efficiency.





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High-efficiency details, such as warm spacers at window assemblies, prevent heat loss/gain by providing a thermal break at conductive materials, like metal-to-metal connections.

Quantifying Glazing Performance

Let's look briefly at the science behind these claims. The energy efficiency of building materials is broadly defined by their ability to conduct or resist energy transfer. For fenestration, energy performance is defined in two ways:

- **Solar heat gain coefficient (SHGC),** a measure of how much of the sun's heat transmits through the windows and into the building interior.
- **Thermal transmittance (U-factor),** a material or assembly's propensity to conduct energy. U-factor is the inverse of R-value, a measure of resistance to energy transfer.

Within a building, most heat accumulation attributable to radiation is the result of solar heat gain through the glazing. However, reducing the SHGC of windows is a tradeoff, for as SHGC diminishes so too does visible light transmission (VLT), a measure of glass transparency.

As with heat gain, most energy loss at the building enclosure also takes place through glazed assemblies. This tendency is reflected in the maximum allowable U-factor established by the IECC, which is higher for fixed fenestration than for mass walls by a

Window performance testing establishes thermal efficiency and moisture protection.

factor of three.

In the design and construction industry, it is now generally accepted that fully glazed walls are not necessary to achieve optimal daylighting or visibility.

According to the U.S. Green Building Council's Leadership in Energy and Environmental Design Reference Guide for Building Design and Construction, only window areas from two feet, six inches to seven feet, six inches above the floor are considered "vision glazing." Windows below this "do not contribute to the daylighting of interior spaces," according to the USGBC.

Despite the established advantages of limiting glazing area, there are reasons designers or building owners might incorporate a greater proportion of glass than the 30% cutoff. What then?

Building Envelope Tradeoff Option

Rather than plug in the energy-efficiency values set by the IECC in the prescriptive path to compliance, the project team would need to model the building to demonstrate that it will perform as efficiently as one with the requisite percentage of glass.

Typically, such modeling follows the IECC methodology for the Building Envelope Tradeoff Option, which enables designers to make up for inefficiencies in certain elements of the building enclosure (in this case, a preponderance of glass) through superior performance of other assemblies, such as opaque walls, roofing, or lighting. However, depending on how far the proportion of vertical fenestration exceeds the prescribed maximum, compensatory efficiencies in other building systems may become cost-prohibitive or not in keeping with design requirements.

UNDERSTANDING THERMAL EFFICIENCY

To quantify a material's ability to resist the transfer of energy—to act as an insulator, rather than a conductor—the design and construction industry uses R-value, the reciprocal of U-factor (the tendency to transfer energy). In most cases, the IECC and ASHRAE 90.1 provide standard R-value and U-factor numbers of materials and assemblies, but to understand what an "energy-efficient" building envelope really entails, it's useful to consider what these values represent in terms of performance.

The most straightforward path to energy code compliance is the R-value method, whereby an exterior wall achieves conformance if insulation of a certain R-value is provided (as per IECC Table C402.1.3). Although adding a thick layer of insulation may seem the simplest way to meet energy-efficiency standards, the complexity of modern building envelope systems may render this method impractical, or even impossible.

A second path to compliance is the whole-assembly U-factor method. In this approach, the thermal efficiency of the entire wall assembly is calculated to determine the overall U-factor, which is then compared to the maximum values set by the code (per IECC Table C402.1.4). In practice, the whole-assembly method is likely the more complicated path to compliance, as the thermal values used for the various wall components are strictly dictated by ASHRAE 90.1. When modeling an enclosure to demonstrate conformance, other material characteristics, such as heat capacity, must be taken into consideration.

COMBATING AIR AND VAPOR MIGRATION

A code-compliant, properly designed, energy-efficient building enclosure relies not only on adequate insulative performance, but also on comprehensive control of the flow of air and moisture. The American Society of Heating, Refrigerating and Air-Conditioning Engineers' ASHRAE Handbook – Fundamentals warns that "improving a building envelope's energy performance may cause moisture-related problems," and advises that "only a sophisticated moisture control strategy can ensure hygienic conditions and adequate durability for modern, energy-efficient building assemblies."

Since heat, air, and moisture transfer are interrelated, the building envelope design must not treat each separately, but, rather, should effectively integrate comprehensive management of hygrothermal forces (i.e., heat and humidity). Evaporation and removal of water are of paramount concern.

Designing Comprehensive Air Barrier Systems

The primary purpose of an air barrier system is to reduce the flow of air between the building interior and exterior. However, air barriers may also restrict the migration of water vapor. Since excess moisture can lead to premature deterioration of building components, the design should consider the impact of air barrier assemblies on water retention.

Design and installation of appropriate and comprehensive air barriers is mandated by the IECC (Section C402.5), which stipulates that air barriers must be continuous "throughout the building thermal envelope." To achieve compliance, care should be taken to provide continuity of the air barrier across changes in the building envelope. Large-format detail drawings are especially critical to illustrate air barrier installation at transitions in materials and assemblies, changes in plane, and intersections with fenestration and roof areas. Particularly at seams and transitions, the air barrier must be designed and installed to resist forces that tend to deteriorate the assembly, such as expansion/contraction and differential movement.

Implementing Vapor Control

IECC requirements for vapor control are less stringent than for air barriers. Without a comprehensive air barrier system to restrict air flow, vapor control strategies are largely ineffective. The extent to which vapor management is needed, and the appropriate design of such a system, is dictated by:

- Climate
- Building use and construction
- Potential sources of moisture beyond interior water vapor

Design consideration should be given not only to keeping water vapor out, but also to allowing moisture to escape when the building enclosure gets wet. To permit the exterior envelope to dry, a semipermeable vapor retarder may be specified. In other cases, a system with very low permeance may be appropriate, so the architect or engineer should evaluate the building, climate, and situation and design accordingly.

When vapor retarders are required, their placement relative to the insulation layer of the wall assembly is extremely important. Typically installed on the warm side of the insulation, "the retarder should be at or near the surface exposed to higher water vapor pressure and higher temperature," according to the ASHRAE Handbook – Fundamentals. ASHRAE 160 – Criteria for Moisture Control Design Analysis in Buildings is a

For some buildings, it may be less environmentally costly to leave windows as is than it would be to replace them.

ENERGY-EFFICIENCY CONSIDERATIONS FOR EXISTING BUILDINGS

Applying new energy requirements to existing buildings can be a difficult undertaking. How do we assess the current thermal performance of the exterior enclosure of a building constructed in the 1940s? If we're replacing 10 sf of a façade, should we install an air barrier as part of the replacement system, even if the rest of the building was constructed without one?

Chapter 5 of the 2015 International Energy Conservation Code addresses the issue of energy performance when working on existing buildings. The IECC tries to strike a balance between the need to achieve a high level of performance and the financial and practical limitations inherent to upgrading existing assemblies. Section C501.2 establishes the intent, stating, "…this code shall not be used to require the removal, alteration, or abandonment of, nor prevent the continued use and maintenance of, an existing building or building system lawfully in existence at the time of adoption of this code." The IECC expands on this concept by exempting historic buildings from conformance with the energy code when "compliance … would threaten, degrade, or destroy the historic form, fabric, or function of the building."

There are good reasons for this. From a practical perspective, mandating that entire building systems or assemblies be brought up to current code standards, when only a portion of that system is affected by a scope of work, could cause financial hardship and a huge disruption to the building's activities.

There is also a case to be made for the impact such far-reaching alterations would have on the environment. Existing buildings have embodied energy, a measure of the resources consumed to originally manufacture or extract materials and construct, say, a building façade. That energy can then be compared to the additional energy required to remove that façade and replace it with a new one. Often, preserving the embodied energy of the built environment by only addressing the portion of an assembly that requires repair has a greater benefit to the environment than the increased energy efficiency realized by complete replacement.

The IECC discusses in some detail whether alterations require compliance with the code when portions of existing systems or assemblies are modified or replaced. New windows, for instance, need to comply with the energy code, while storm windows installed over existing fenestration do not.

The code also makes a distinction between "alterations" and "repairs," exempting the latter from compliance. Additions to existing buildings are afforded no such latitude and are regarded as new construction by the IECC, requiring full compliance with the code.

recognized standard for evaluating the need for and placement of vapor retarders.

Dealing with Condensation

When humid air contacts a cool surface, water vapor changes from gas to liquid, collecting in droplets through the process of condensation. To prevent water damage, insulation should be thick enough to maintain the surface above the dew point, the temperature at which condensation can occur.

Even without reaching the dew point, persistently high relative humidity can still create problems, notably mold growth. Under the right conditions, though, a limited amount of interstitial condensation can be tolerated, provided there is ample opportunity for the assembly to dry. Analysis of moisture migration is complicated, and an accurate evaluation requires consideration of numerous variables within the building system.

PROVIDING HIGH-EFFICIENCY DETAILING

Unfortunately, the danger of overreliance on simplified models is not limited to condensation analysis. Thermal efficiency calculations, too, tend to oversimplify the behavior of the system. Analyses used to determine energy code compliance for opaque wall assemblies, including the R-value method and whole-assembly U-factor method, may overrate insulating value by as much as 80%.

What these models fail to consider, primarily, is thermal bridging, whereby highly conductive materials pass through insulation layers and transmit heat across the wall assembly. Generally, thermal bridges can be grouped into two categories, based on their geometry:

- **Linear transmittances,** where heat flows across the exterior wall along a two-dimensional length, such as at floor slab edges, parapets, window and door heads/sills/jambs, and the base of walls
- **Point transmittances,** which transfer heat at a single point of intersection between the wall and another object, such as at beam penetrations.

How significant is the impact of thermal bridging on energy performance? For a simple opaque exterior wall, the clear field, or basic wall assembly without penetrations, might have an R-value that falls well within the prescriptive requirements for the climate zone and type of construction. However, factoring in linear transmittances could reduce the total R-value by more than 50%.

This reduction in performance illustrates the importance of eliminating linear and point transmittances in building enclosure design as much as possible. High-efficiency detailing considers these potential sources of energy loss and incorporates thermal breaks that insulate against heat transfer at windows, doors, floor slabs, roof edges, and the bases of walls.

The latest version of ASHRAE 90.1 now requires that linear transmittances must be accounted for in energy-performance calculations. Updated requirements for the Building Envelope Tradeoff Option (ASHRAE 90.1, Normative Appendix C) stipulate that uninsulated assemblies, such as projecting balconies, roof parapets, and floor slab edges, must be separately modeled to achieve compliance.

WHEN HIGH-EFFICIENCY ENCLOSURES GO WRONG (AND WHAT TO DO NEXT)

If high-efficiency enclosures are designed incorrectly, they can actually have an adverse impact on performance. Common problems include:

- Condensation
- Drafts and cold spots
- Mold growth
- Premature deterioration of building materials and assemblies
- Scant energy savings and increased costs

Ironically, even when they are designed correctly, high-efficiency building enclosures can still succumb to problems. Notably, the comprehensive insulating of the building envelope has led to increased problems with snow and ice build-up on the exterior of buildings. To compensate for the thermally insulated enclosure's tendency toward moisture accumulation in the colder months, the design professional can include provisions to optimize weather integrity while maintaining peak energy performance.

THE FUTURE OF ENERGY-EFFICIENT BUILDING ENVELOPES

As states continue to seek opportunities to reduce energy consumption, more attention will be paid to building envelope details that reduce inefficiencies. Incorporation of design details that minimize energy loss can result in improved indoor comfort, as well as cost savings through smaller heating, ventilation, and air-conditioning (HVAC) packages and reduced utility bills.

To balance performance and practical considerations, an energy-efficient enclosure should apply principles of energy transfer, heat loss, and moisture migration. By considering how energy code requirements are derived and why certain design factors impact performance, building owners, managers, and design professionals are better positioned to develop building envelope solutions that achieve real-world efficiency demands without compromising aesthetics, comfort, or longevity. +

+EDITOR'S NOTE

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