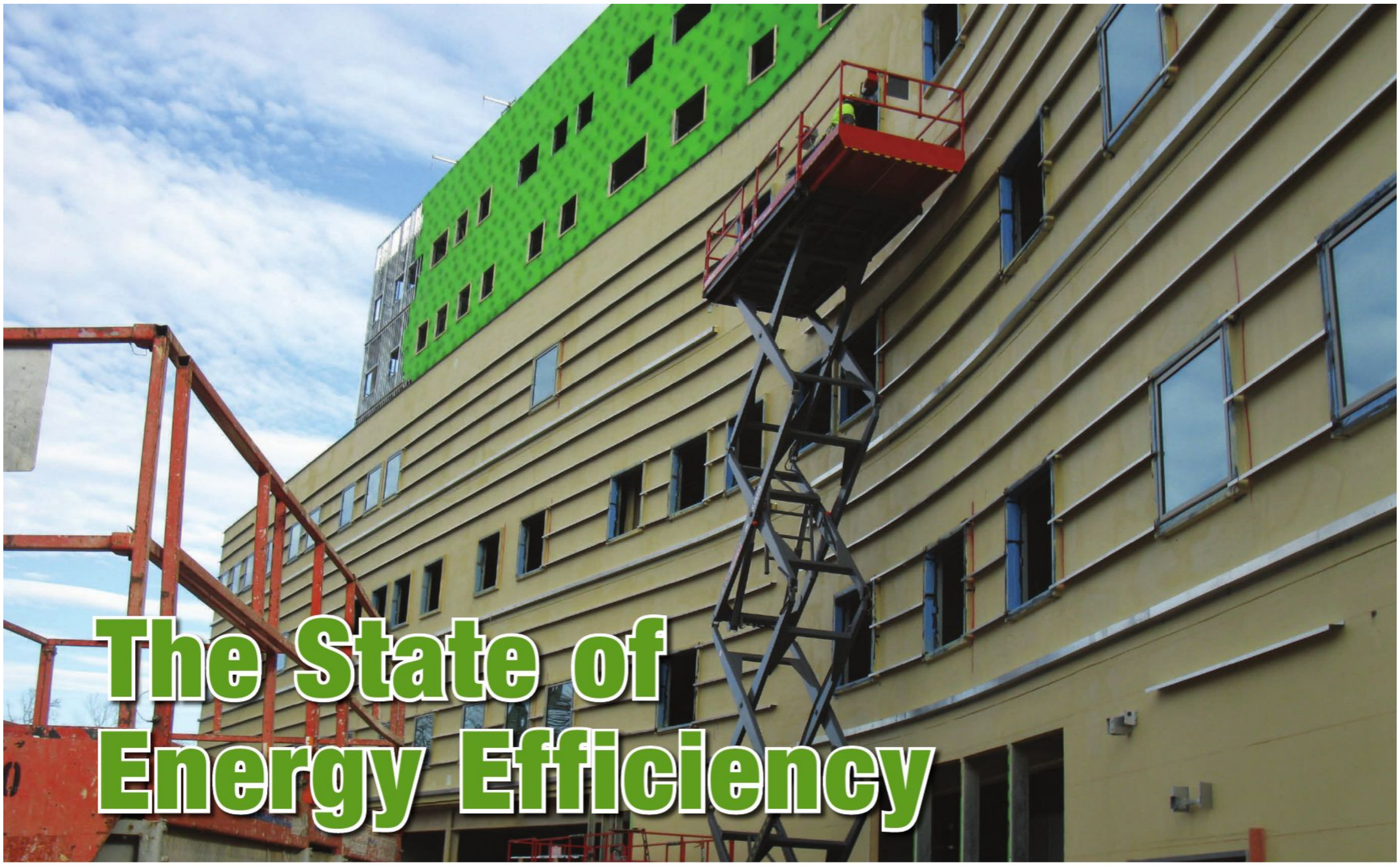

The State of Energy Efficiency

The *International Energy Conservation Code* (*IECC*) and the building enclosure

by Craig A. Hargrove, AIA, LEED AP

All images courtesy Hoffmann Architects

ON 24 FEBRUARY, 2017, *THE NEW YORK TIMES* RAN AN ARTICLE REGARDING THE EVENTUAL DE-COMMISSIONING OF THE INDIAN POINT NUCLEAR POWER PLANT JUST NORTH OF NEW YORK CITY. ACCORDING TO THE ARTICLE, THE GOVERNOR INTENDS TO CLOSE THE PLANT BY 2021. THIS RAISES THE QUESTION: HOW DOES NEW YORK STATE INTEND TO REPLACE THE ENERGY THE PLANT CREATED SO THEY CAN STILL MEET POWER DEMANDS?

As it turns out, they do not; not entirely. The article goes on to cite a report that determined New York's best option is not finding alternative sources of power, but to follow states like Massachusetts and Rhode Island in enacting programs to reduce energy use.

New York is not alone in applying this calculus to energy policy, and the cumulative effect such decisions have on the built environment is significant. In 2010, the required insulative value for a new, low-sloped roof on a commercial building in climate zone 4 (the region that includes New York City) was R-20. Today, the 2018 *International Energy Conservation Code* (*IECC*) requires that same roof to have a value of R-30—a 50 percent increase. For windows, the change has been even more dramatic. In 2010, new fixed windows needed an R-1.82; today it is R-2.63—a 45 percent increase. Further, while similar values for exterior walls have remained largely the same, the method of assessing performance has changed greatly.

The 2018 *IECC* is the latest in a line of increasingly stringent regulatory requirements. While it is not necessarily a response to, these regulations certainly support a shift in policy being adopted by states like New York that seek to meet energy needs in part by reducing usage.

Today, the path to energy code compliance can be nuanced and complicated, requiring knowledge not just of standards and materials, but a basic understanding of scientific concepts like the laws of thermo- and fluid-dynamics. Stricter requirements now bring designers into potential conflict with

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competing codes on issues like combustibility and structural stability. It is, of course, unlikely this trend will ever reverse itself. Instead, the requirements for energy performance will simply continue to become more stringent and paths to compliance will be more complicated. With all of this in mind, an overview of the 2018 *IECC* and the science behind it might be helpful. To simplify things, the discussion in this article will be limited to commercial buildings.

Since its introduction in 2000, some version of *IECC* has been adopted in 48 states, the District of Columbia, and the U.S. Virgin Islands.[1] The code incorporates the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 90.1-2016, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, by reference. While *IECC* incorporates approximately 87 outside publications by reference, these two standards (*IECC* and ASHRAE 90-1-2016) create the essential framework for establishing and demonstrating compliance with the mandated energy performance requirements of the building enclosure. During this discussion, unless otherwise stated, 'code' refers to the combined requirements of *IECC* and ASHRAE 90.1.

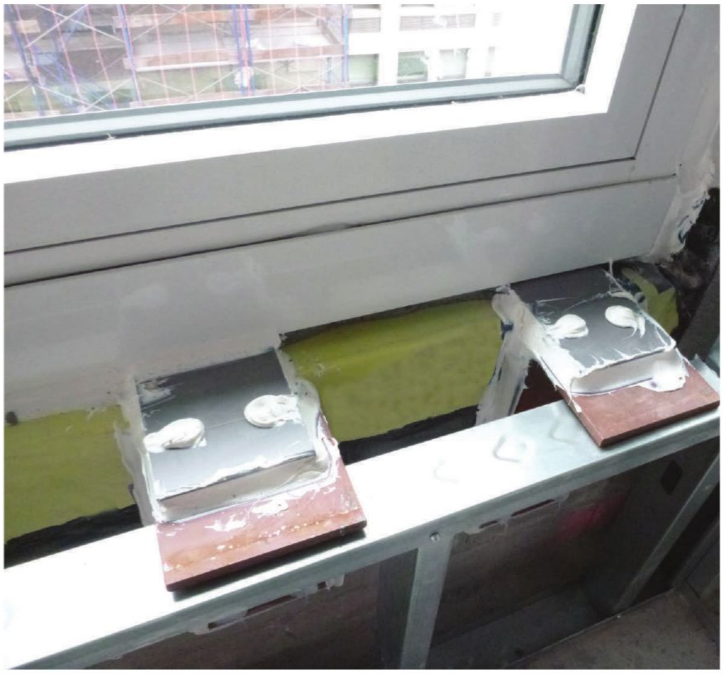
Climate

To understand the code, it is important to grasp that a path to compliance is entirely dictated by geography. Different locations require different strategies to achieve energy efficiency, and the first question to ask is: Is the project in a 'heating' or 'cooling' climate? The terms mean exactly what they might seem—in a heating climate there are more annual 'heating degree days' than 'cooling degree days,' and vice versa. While the code has specific definitions for these conditions, simply stated, a heating climate is one in which more days are spent heating the building than cooling it. For example, Boston is in a heating climate, while Miami is in a cooling zone.

ASHRAE 90.1 further divides the continental United States into seven climate zones that can broadly be defined as varying degrees of the following conditions:

- moist heating climate;
- dry heating climate;
- moist cooling climate; and
- dry cooling climate.

So, in general, the code establishes requirements in a region based on two criteria: temperature and moisture. The control of these two conditions is essential for thermal comfort and energy efficiency.



An example of high-efficiency detailing, where a thermal break is provided at point transmittances, such as metal-to-metal connections.

Understanding thermal efficiency

Every material used in construction can resist the transfer of energy—this is its R-value. The reciprocal of a material's R-value is its U-factor, or its tendency to transfer energy. R-values of many common building materials can be found in ASHRAE 90.1 in, for instance, Table A9.4.3-1, "R-values for Building Materials." Manufacturers are also good sources for R-values of specific products. However, it is always advisable to verify such claims by a review of test data supporting the published values.

The prescriptive requirements of the code for, say, opaque wall assemblies can be met in one of two ways. The first is the "R-value method," where an exterior wall is deemed in conformance if insulation of a certain R-value is provided as indicated in *IECC*, Table C402.1.3, "Opaque Thermal Envelope Insulation

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

Component, Minimum Requirements, R-Value Method." This is the most straightforward path to compliance, but is not always possible or the most practical.

A second path to compliance is the "whole assembly U-factor" method. In this case, the thermal efficiency of the entire wall assembly is calculated to determine the overall U-factor, and that amount is, in turn, compared to the maximum values in *IECC*, Table C402.1.4, "Opaque Thermal Envelope Assembly, Maximum Requirements, U-Factor Method." This is a more complicated path to compliance, as the thermal values used for the various wall components are strictly dictated by Normative Appendix A, "Rated R-Value of Insulation and Assembly U-Factor, C-Factor, and F-Factor Determinations," of ASHRAE 90.1. However, this method often offers an advantage to designers when placement of the amount of insulation dictated by the prescriptive requirements of the code proves impractical.

The path to compliance

As discussed, the code provides prescriptive values for the building enclosure, minimum requirements components like roofs, walls, and fenestration must meet. Whether or not one can avail of those values depends on the amount of glass on the building. Section C402.4.1, "Fenestration (Prescriptive), Maximum area," of *IECC* states (with some exceptions):

> The vertical fenestration area (not including opaque doors and opaque spandrel panels) shall not be greater than 30 percent of the gross above grade wall area.

With the use of prescriptive values being the easiest path to code compliance, why would the International Code Council (ICC) restrict its use based on the amount of glass on a building façade?

As it turns out, most of the inefficiency that is experienced at the building enclosure is through the fenestration. The second law of thermodynamics states that energy flows from hot to cold, so, in the summer, windows, being the most thermally inefficient portion of the enclosure, will warm the cool, conditioned air of the interior, requiring more energy to achieve thermal comfort. This happens in two essential ways: through conduction and convection (the transfer of energy through and across the assembly), and via solar radiation. Glazed assemblies are made more energy efficient by reducing the amount of energy it can transfer by decreasing its overall U-factor and solar heat gain coefficient (SHGC). These performance improvements are achieved in a variety of ways, including thermal separations at metal frames, internal frame components such as warm spacers, glass coatings, and inert gases such as argon and krypton between the panes of insulating glazing units (IGUs).

Yet, fenestration is still a weak point in the quest for thermal efficiency and code compliance. There is documentation supporting the notion that limits to the amount of exterior glass in a room does not necessarily reduce the user's well-being. The U.S. Green Building Council (USGBC), for instance, has stated, "window areas below 0.6 m (2.6 ft)" do not contribute to daylighting of interior spaces and [should] be excluded."[2]

The code recognizes that glazed assemblies are inefficient when compared to the opaque portions of the building enclosure, and more glazing is often unnecessary to achieve a desired indoor environment. As a result, both *IECC* and ASHRAE 90.1 attempt to encourage the reduction of glazing by restricting the use of prescriptive values and requirements within the code. While this requirement is not new, large glass towers have not exactly disappeared from the landscape. So how do these buildings establish a path to compliance when they have more than the required percentage of vertical fenestration?

In such cases, compliance lies in the ability to 'model' the building to show it performs as efficiently as a building with the requisite percentage of glass (the 'budget building'). This can be accomplished in several ways, but most often means following the requirements of Normative Appendix C, "Methodology for Building Envelope Trade-Off Option," as further defined by Section 5.6, "Building Envelope Trade-Off Option," of ASHRAE 90.1. This option enables designers to make up for inefficiencies in certain elements of the building enclosure (in this case, a preponderance of glass) by trading off with systems performing in excess of the code requirements, such as opaque wall assemblies, roofing, or lighting. Depending on the amount of vertical fenestration, such trade-offs could tax the abilities of these other systems to compensate in ways that fit the design requirements and do not become cost prohibitive.

The ramifications of having too much glass, and then having to employ alternative paths to code compliance such as the "Building Envelope Trade-Off Option," do not end there. Starting in 2013, ASHRAE 90.1 included the following statement in Normative Appendix C:

Opaque walls and fenestration must form a uniform air barrier providing the requisite protection from leakage, even across joints and transitions.

> C1.2.6 For Uninsulated Assemblies. All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor slabs, concrete floor beams over parking garages, roof parapet) shall be separately modeled.

Less than 30 words, and yet, it has significant implications in how the façade of a building is assessed for thermal performance. Under the prescriptive requirements, an opaque wall assembly's ability to resist thermal transfer (its R-value or U-factor) has traditionally been established by an analysis of its 'clear wall value.' In other words, by assessing "a portion of the wall containing only insulation and a minimum of necessary framing materials at a clear section with no windows, corner columns, architectural details, or interfaces with roofs, foundations, or other walls."[3] The result is an optimal assembly presenting the best possible performance of that wall for energy.

However, this is not reality. What an analysis of this portion of the wall fails to consider are the host of conditions in a façade that can lead to thermal transfer: the linear and point transmittances. Examples include:

High percentages of glass require compensatory efficiencies in other systems.

- parapets;
- uninsulated slab edges;
- window heads, sills, and jambs; and
- façade cladding anchors.

When these transmittances are accounted for, the actual insulative value of a wall can be reduced by as much as 60 to 70 percent.[4]

By including C1.2.6 in Normative Appendix C, ASHRAE's message is clear: reduce the amount of glass on buildings or switch to high-efficiency detailing to address all thermal inefficiencies on the building enclosure.

It should be noted the use of high-efficiency detailing to eliminate thermal transfer at façade transmittances can represent a net cost savings to owners. By establishing a more efficient building enclosure during design, the size of mechanical systems and subsequent utility costs could be significantly reduced.

Air and vapor migration

This article has discussed how the key to thermal efficiency is the control of temperature and moisture. Up until now the focus of this has been on temperature, but clearly that is only part of the equation.

> Because heat, air, and moisture transfer are coupled and closely interact with each other, they should not be treated separately. In fact, improving a building envelope's energy performance may cause moisture related problems. Evaporation of water and removal of water by other means are processes that may require energy. Only a sophisticated moisture control strategy can ensure hygienic conditions and adequate durability for modern, energy-efficient building assemblies. Effective moisture control design must deal with all hygrothermal loads (heat and humidity) acting on the building envelope.
> *ASHRAE Handbook – Fundamentals* (2013)

While limiting the infiltration of liquid water is essential for the health and sustainability of a building, any discussion about the control of moisture in regard to energy efficiency is really about the control of air and water vapor.

The design and installation of appropriate and comprehensive air barriers are mandated by Section C402.5, "Air leakage–thermal envelope (Mandatory)," of *IECC* and must be continuous "throughout the building thermal envelope." As the name suggests, an air barrier system's primary purpose is to reduce the flow of air between the interior and exterior. However, it may also serve a secondary purpose of restricting the flow of water vapor.

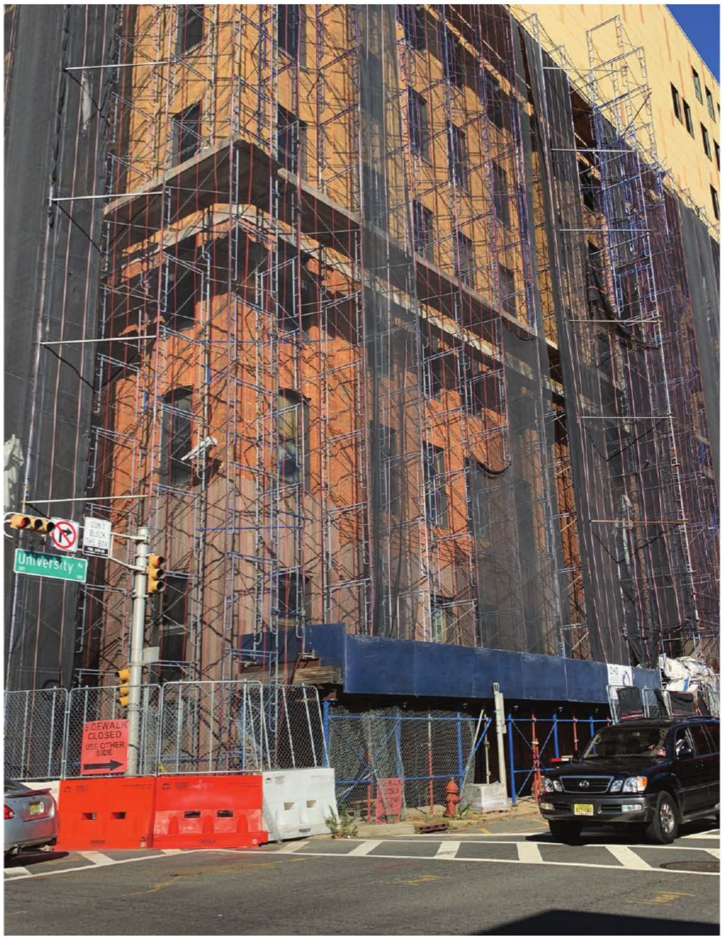
Providing a comprehensive and contiguous air barrier "throughout the building thermal envelope" is a complex undertaking, and particular care should be taken in its design. Large-format details showing the continuity of the air barrier across changes in the thermal envelope should be developed, including at the field of the opaque wall assembly and its interface with:

- transitions in materials and assemblies;
- changes in plane;
- fenestration; and
- roofs.

The barrier must be designed and installed to resist forces that may deteriorate the assembly, particularly at seams and transitions. Additionally, entrances may require vestibules depending on their size, use, and climate zone location.

Standards for air barrier performance are very rigorous, and installed barrier systems, which include fenestration, must undergo testing to see they do not admit more air leakage than is permissible. Materials used in the opaque wall assembly must comply with ASTM 2178, *Standard Test Method for Air Permeance of Building Materials*, and "shall be deemed to comply…provided joints are sealed and materials are installed as air barriers in accordance with the manufacturer's instructions." Doors, windows, and skylights must conform to ASTM E283, *Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*. Together, opaque walls and fenestration must form a uniform air barrier providing the requisite protection from leakage, even across joints and transitions.

While the requirements for the control of air through the building enclosure are stringently mandated, the requirements for vapor control are less so. This may seem counterintuitive, but there is a compelling reason. Energy efficiency and vapor control strategies are ineffective without a comprehensive air barrier system to restrict airflow. However, the extent to which a vapor control strategy is needed and how it should be designed and installed depends on several variables, including climate, building use and construction, and the potential and the extent to which moisture sources other than interior water vapor exist. ASHRAE 160, *Criteria for Moisture Control Design Analysis in Buildings*, is a recognized standard for evaluating the need for and placement of vapor retarders.



Every material used in construction can resist the transfer of energy.

Additionally, consideration should be given not just to vapor control, but to the need of the building enclosure to effectively dry after it gets wet. This may require a 'semipermeable' vapor retarder, while in other cases, systems with a very low permeance may be appropriate. Care should be taken during design to avoid the potential to trap moisture through the inadvertent use of multiple vapor retarding layers in an assembly.

When vapor retarders are required, their placement relative to the insulation layer of the wall assembly is extremely important.

The retarder should be at or near the surface exposed to higher water vapor pressure and higher temperature. In heating climates, this is usually the winter-warm side.
ASHRAE Handbook – Fundamentals (2013)

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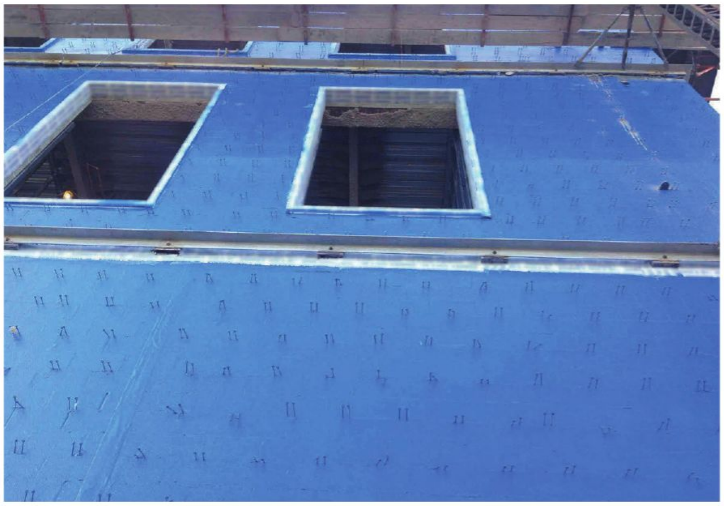

Addressing thermal flow at linear transmittances, such as the relieving angle shown, is now being required under certain conditions by code.

In other words, the vapor retarder is often installed on the 'warm side' of the insulation.

As always, proper installation is as important as proper design. In the case of vapor retarders, a significant increase in permeance can occur as a result of very small holes in the material.

Condensation

Surface condensation occurs when water vapor contacts a non-porous surface that has a temperature lower than the dew-point of the surrounding air. Insulation should therefore be thick enough to ensure that the surface temperature on the warm side of an insulated assembly always exceeds the dew-point temperature there. However, even without reaching the dew-point, relative humidity at the surface may become so high that, given time, mold growth appears."
*ASHRAE Handbook – Fundamentals (*2013)

An unfortunate byproduct of the strides toward thermally efficient buildings is the increased propensity for condensation in buildings through the effective separation of interior and exterior environments. Limited interstitial condensation can often be tolerated under the right conditions and provided there is ample opportunity for the assembly to dry out. However, chronic condensation can be detrimental to things like the health of the building and indoor environmental air quality.

Analysis of moisture migration within a system is extremely complicated and requires an understanding of numerous variables within that system. However, a simplified analysis is often used to make certain broad-based assumptions regarding the potential for condensation to occur. If such an analysis is of a 'steady-state' system, results are achieved by reducing

> Glazed assemblies are made more energy efficient by reducing the amount of energy it can transfer by decreasing its overall U-factor and solar heat gain coefficient (SHGC).

the number of variables and, by extension, the model's resemblance to actual conditions. The results are limited, and extreme care should be used when deriving conclusions from them. Simplified condensation analysis in a steady-state environment, while instructive, does not provide a comprehensive picture of the effects of hygrothermal flow across an assembly. One problem is that it neglects to account for the effects of vapor pressure, which can create conditions conducive to mold, material failure, and displacement of assemblies.

The road to net-zero

In 2017, residential and commercial buildings accounted for 39 percent of the nation's energy consumption.[5] Changes in climate and government policy, diminishing resources, and an aging infrastructure all underscore the need to create a built-environment that meets a high standard for energy efficiency. Clearly, *IECC* continues to evolve with this goal in mind.

Out of necessity, this process is a protracted one, with the mandates of code being balanced against their potential impact on the economy, the limitations of available technologies, and other practicalities. However, net-zero buildings—structures whose net energy use is zero—exist, and while they are currently few, the number grows each year.[6] While incremental changes to the code are prudent, the cumulative result over the coming decades could be quite remarkable. **CS**

Notes

[1] Visit www.iccsafe.org/wp-content/uploads/Code_Adoption_Maps.pdf.

[2] Get more information from the U.S. Green Building Council's *New Construction and Major Renovation Reference Guide* (Version 2.2, Second edition, September 2006).

[3] Consult Building Science Corporation at www.buildingscience.com/glossary/clear-wall-r-value.

[4] For more information, read British Columbia Hydro's *Thermal Envelope Bridging Guide*, Version 1.1, 2016.

[5] Access details at www.eia.gov/tools/faqs/faq.php?id=86&t=1.

[6] For more information, visit www.wbdg.org/resources/net-zero-energy-buildings.

ADDITIONAL **INFORMATION**

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Key Takeaways

As federal, state, and local governments continue to look for ways to reduce energy consumption in their jurisdictions, the requirements for the construction of energy-efficient buildings becomes increasingly stringent. Often this means more efficient lighting, heating, and cooling systems. However, no building system has the potential to affect energy use as much as the building enclosure. This article provided an overview of the 2018 *International Energy Conservation Code (IECC)* and explained how the current code will impact building design and construction.

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