

# DESIGNING FOR ENERGY PERFORMANCE

Presented by:



## LEARNING OBJECTIVES

Upon completion of this course the student will be able to:

- Identify the current code requirements related to energy performance of buildings.
- Determine the differences between prescriptive and performance requirements.
- Strategize how to best meet the intent of the code based on site specific conditions.
- Understand the roles that insulation, air barriers, and vapor retarders serve in energy performance.

## CONTINUING EDUCATION

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By Peter Babaian and Ken Lambert

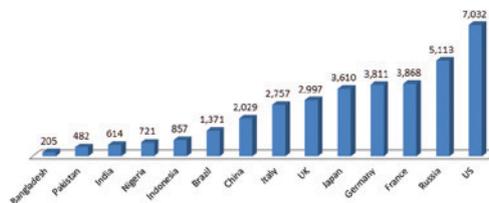
## INTRODUCTION

Most, if not all, architects and contractors are aware of the strong push being made over the past several years towards greater energy efficiency and a reduced carbon footprint in the United States. Worldwide geopolitical pressure has helped to steer the U.S. in this manner, as it is often noted that the U.S. uses more energy than any other nation per capita.

One specific example of this directive is Executive Order 13514, signed in 2009, that mandates that federally-owned buildings drastically improve their energy efficiency by the year 2030. The U.S. government is the largest consumer of energy in America and has roughly 500,000 buildings; most of these buildings are not energy efficient. Many states and cities have followed suit for their own public properties.

For the past decade plus, energy codes continuously increased their requirements for

Energy Use per Capita



The U.S. uses more energy than any other nation per capita. Image courtesy of Wikimedia Commons

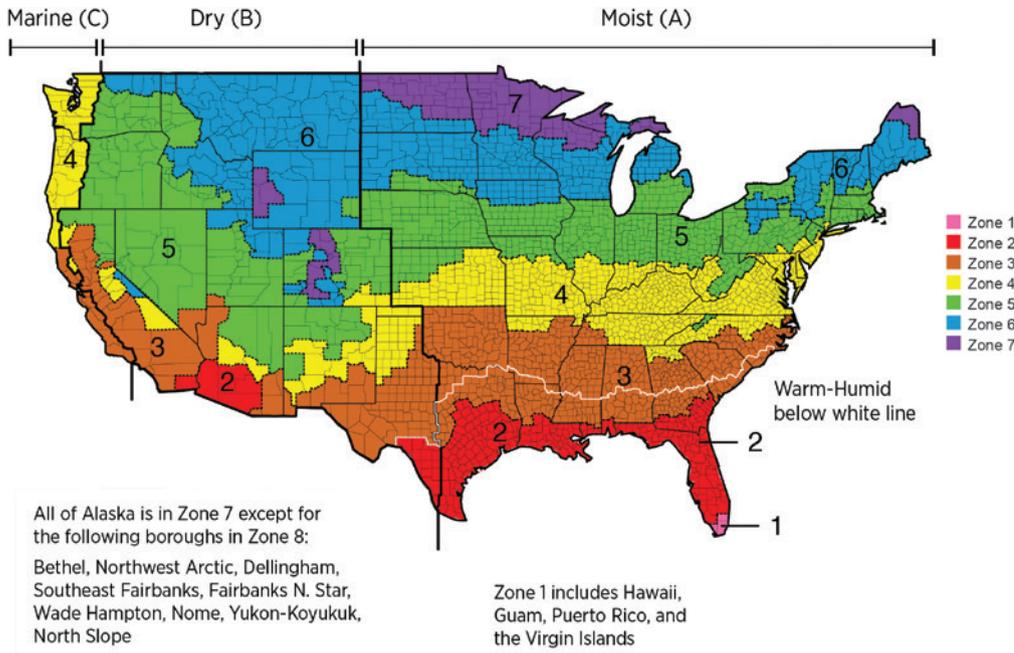
energy efficiency of buildings to reduce the estimated 40 percent total energy consumption in the United States related to the building stock. Codes began by increasing insulation requirements and recently added an air barrier requirement to reduce air leakage of conditioned air. As more and more states adopt the latest I-Codes, these requirements will become ubiquitous.

The codes include prescriptive and performance requirements; however, the prescriptive

requirements are what most designers utilize. Following the prescriptive requirements without consideration of the environmental conditions, both exterior and interior, can result in unintended consequences for wall and roof systems. Misuse of air barriers and vapor retarders can result in unintended system deterioration. "Systemization," having an understanding of, and specifying the performance of, the entire system is essential. This article will discuss the current state of the code requirements, both prescriptive and performance, as well as when prescriptive requirements may result in inadequate system performance.

## FACTORS AFFECTING ENERGY PERFORMANCE

Many factors affect the energy performance of buildings. For this course, we will highlight several other factors besides the building enclosure that should be included as part of the design consideration and how they interact



International Energy Conservation Code Climate Zone Map—Energy consumption necessary to maintain comfortable ambient indoor temperatures and humidity levels will vary based on region. Map courtesy of IECC

with the building enclosure. We will then cover the building enclosure in more detail.

**Location and Climate Zone**

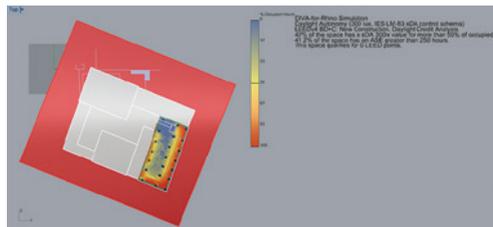
Location, and more specifically climate zone, is the first key step in proper design for buildings. ASHRAE (American Society for Heating, Refrigeration, and Air-Conditioning Engineers) publishes a US climate zone map, adopted into the International Energy Conservation Code. Energy consumption necessary to maintain comfortable ambient indoor temperatures and humidity levels will vary based on region. The same building with the same design, construction, and enclosure solutions in Texas will perform differently when placed in North Dakota. So all buildings must be designed based on location-specific climate information. Locales where the climate is nearly perfect year-round, such as San Diego, should result in less energy use for buildings. Of course, since we cannot all live in San Diego, we need to adapt our building enclosure to the specific location of the country.

**Siting**

Siting can have a major impact on the building’s energy performance. Buildings at elevation, in locations of high wind exposure, subject to direct sunlight, etc., can require more energy to operate. Utilizing natural surroundings to shelter buildings or balancing the exposures can



Siting can have a major impact on the building’s energy performance. Photo courtesy of de Oliveira Castro Arquitectos



Where the building faces in relation to the arc of the sun, and how this relates to the length and size of roof overhangs, can make a significant difference. Image courtesy of Simpson Gumpertz & Heger

be very beneficial in reducing energy use. For instance, daylighting can reduce a building’s need for energy to power lighting systems. However, it can also lead to solar heat gain and increased cooling loads. But done in a cold environment, this can also result in lower

heating loads. The building enclosure solution needs to account for these possibilities and balance the competing requirements.

Where the building faces in relation to the arc of the sun, and how this relates to the length and size of roof overhangs, can make a significant difference. The specialization of passive solar heating, for example, intertwines with all of these listed energy efficient subcategories.

**Lighting**

Lighting is often the most significant energy load in a building. The lighting system selection is critical to energy usage. In existing buildings, it is often the easiest place to find energy savings by switching from energy intensive fixtures, such as incandescent light bulbs, to compact fluorescent lamps to light emitting diodes (LEDs). In new buildings, the need for lighting can be significantly reduced by siting the building in such a way as to allow for significant daylighting to the interiors. The building enclosure design, as previously mentioned, needs to consider the opportunity for daylighting the interior and accommodate it accordingly.

**Mechanical Systems**

A multitude of mechanical systems exist for mechanical engineers to design for a building, including boilers, chillers, heat pumps, and packaged units, just to name a few. These systems can have variable fuel sources, efficiencies, and controls that can affect their performance and energy consumption. In addition, they are sized based on certain assumptions made by mechanical engineers, including the overall thermal performance and expected air leakage of the building enclosure. As a result, a building enclosure solution that does not perform as well as expected can result in a mechanical system that cannot perform, resulting in wasted energy and money.

It is critical that the architect, the overall building designer of record, takes into full account the planned mechanical design—which typically will come from a 3rd party MEP engineer. In some cases where there is not adequate communication and crosschecks between these two professionals, unforeseen building problems can arise.

In either case, be wary of circumstances, especially in MEP design/build projects, where a HVAC subcontractor and/or HVAC equipment supplier is fully designing the building’s system. In both cases, this “designer” has a direct incentive to sell and install larger

equipment—which may not be needed and could in fact be a waste of energy.

### Building Enclosure Solutions

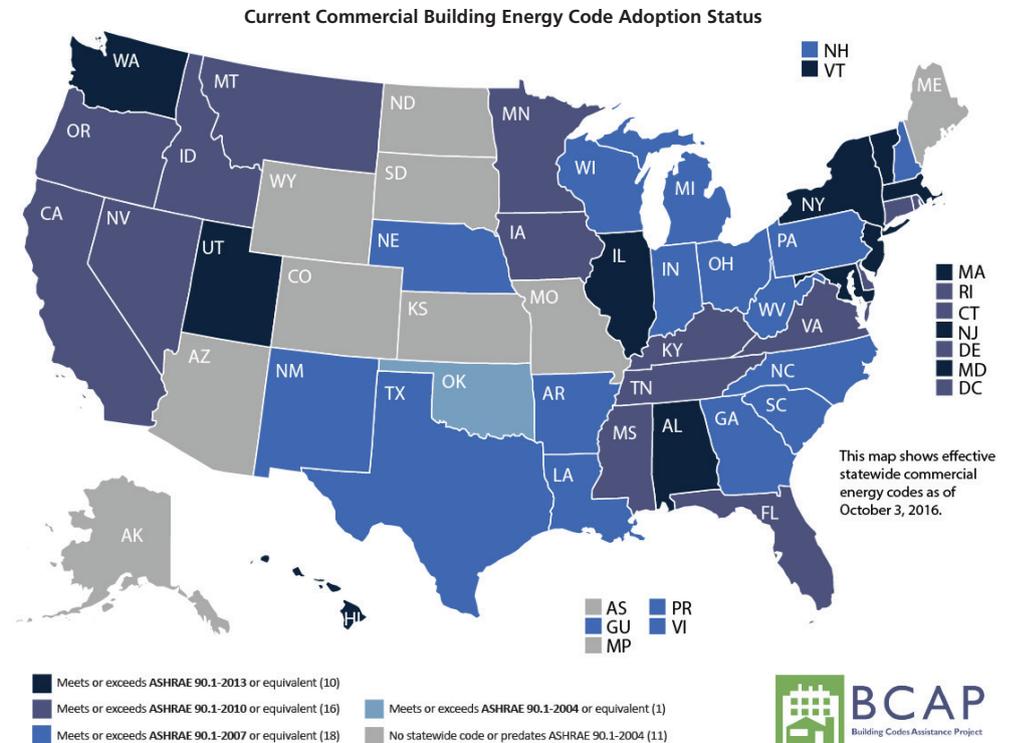
Finally, the building enclosure itself has an impact on the energy performance of the building based on its interactions with the other factors mentioned above as well as its own design and performance. A building that is 250 years old will perform differently than a building designed and constructed in the 1970s or something more contemporary currently in design or construction. Over the years, the industry has moved from heavy, bulky buildings with little to no fenestrations through the enclosure and minimal roof insulation to lightweight and open buildings with a lot of glass and significant amounts of roof insulation.

Glass alone is an enormous factor when it comes to energy consumption, efficiency, and comfort levels. Options for glazing can include: clear, opaque, single pane, double and triple pane, tintings, low-E coatings, argon gas-filled cavities, and various sizes. Each option affects condensation, drafts, heat gain, and indoor temperatures.

The performance of the building enclosure changes with the design. Older, mass masonry buildings rely on the thermal mass and single pane glazing for their insulating capabilities while today we include cavity and/or continuous insulation in our opaque systems and have ever increasingly efficient glass systems for insulation. As a result, the building enclosure is now more complicated than ever to design and construct, resulting in many opportunities for building enclosures to perform below the performance expected of them, which in turn may lead to increased energy use directly or indirectly by affecting one of the previously identified factors. The truth is that understanding only one or two of the “energy criteria” is not enough, and in fact could be detrimental to the building at large. A designer must be cognizant of all major sub-categories and of how systems are specified to ensure maximum performance and code compliance.

### CURRENT CODE REQUIREMENTS

The predominant energy codes in use today are ASHRAE 90.1 and the International Energy Conservation Code (IECC). The most commonly used IECC versions are either the 2012 or 2015 edition, however in some states or localities older IECC editions are accepted. The International Building Code and most, if not all, state or city specific codes reference these



Map courtesy of Building Codes Assistance Project

two documents (referred to in aggregate as the energy codes). In addition, there are some city or county codes which can add more stringent design or performance requirements.

The energy codes have insulation, vapor retarder, and air barrier requirements that the local jurisdictions can then adopt or modify as they see fit. The energy codes also provide three distinct paths to compliance, including meeting prescriptive requirements, utilizing trade-offs in prescriptive and performance requirements, and a performance approach.

### Prescriptive Approach

The prescriptive approach is found in the IECC and mandates that the designer meet a certain prescriptive U-value or R-value (see sidebar to the right) for each enclosure system. In order to use this approach, certain other conditions must be met, including a limitation on fenestration area to total vertical building enclosure area, presently 40 percent, limitations on the solar heat gain, and limitations on the skylight area to the total roof area, presently 3 percent.

The codes have tables of U-values, which are both prescriptive and performance. The reason it can be deemed “performance” is because you actually have to calculate the rate of heat loss/gain to verify that this wall system meets

**R-Values:** The R-value is a measure of resistance to heat flow through a given thickness of material. The higher the R-value, the more thermal resistance the material has and therefore the better its insulating properties.

**U-Values:** The U-value of a building element is the inverse of the total thermal resistance of that element. The U-value is a measure of how much heat is lost through a given thickness of a particular material, but includes the three major ways in which heat loss occurs—conduction, convection and radiation. U-values will vary based on the exact point where one is measuring and analyzing. For instance, the U-value at the center of a window will be much different than the U-value and heat transmittance for the window unit as a whole (glass + weatherstripping/gasketing + frame/sash material, etc).

the listed U-value. It’s not acceptable to merely add up the U-values of the different materials. The assembly is analyzed as a system to ensure that everything in that assembly from exterior cladding to the interior drywall, including all attachments and fasteners, work as an overall U-value for the assembly.

This U-value for an assembly is more of a performance-based approach than a simple prescriptive measure. It is not as simple as stating and checking off a box for the R-value of each building element.

Building construction over the past several years has been leaning more and more towards systems. Many of these system approaches are marketed using products from just one manufacturer. More complete enclosure system performance can be attained through companies that have partnered to cooperatively provide a more complete array of products that address all aspects of system performance. The U-value for enclosure assemblies tie-in well with this overall systems construction approach.

For products or pre-manufactured assemblies such as fenestrations, there exists a specific and clear required U-value. One typically uses the U-value from a product manufacturer, whether it's a window, curtain wall, skylight, etc.

### Trade-Off

The trade-off approach is found solely in ASHRAE 90.1. The trade-off approach allows the designer to compensate for lesser performing components by adding better performing components elsewhere on the building. This often involves increasing the fenestration area, which has a higher U-value than opaque walls, by either increasing the insulation in the opaque walls or the roof. The Department of Energy publishes programs, called COMcheck and REScheck, that perform the calculations for the trade-offs based on the insulating value and relative areas of the systems in question. As the names indicate, COMcheck is utilized primarily for commercial design and construction and REScheck is utilized primarily for residential design and construction.

### Performance Approach

Both the IECC and ASHRAE 90.1 allow a performance based approach to show compliance with the building energy performance requirements. However, they take different approaches to the performance modeling. IECC establishes an annual energy cost of a standard reference design and requires the proposed design to be less than 85 percent of the reference design cost. ASHRAE 90.1 provides an energy cost budget method approach to the performance design compliance path. Under ASHRAE the building is modeled two ways. The first is the proposed design model, which is the building as designed and intended to be constructed. The second is the budget building design, which is the building as designed only with the ASHRAE prescriptive requirements for system performance. The first model must have a lower energy cost than the second model.

## QUIZ

1. True or False: The U.S. government is the largest consumer of energy in America.
2. True or False: Most designers use performance requirements, but following the performance requirements without consideration of the environmental conditions, both exterior and interior, can result in unintended performance of wall and roof systems.
3. True or False: In new buildings, the need for lighting can be significantly reduced by siting the building in such a way as to allow for significant daylighting to the interiors.
4. The energy codes provide \_\_\_\_\_ distinct paths to compliance.
  - a. 2
  - b. 3
  - c. 4
5. Which path to compliance is found solely in ASHRAE 90.1?
  - a. Prescriptive requirements
  - b. Trade-offs
  - c. Performance requirements
6. Which materials are primarily designed to keep liquid water from entering the building enclosure?
  - a. Water resistive barriers
  - b. Vapor retarders
  - c. Air barriers
7. True or False: Combined air barriers, vapor barriers and water resistive barriers can be provided in a single material/product.
8. True or False: Because vapor retarders only prevent diffusion through a material, they must be perfectly continuous, free of holes, lapped, and sealed.
9. True or False: A good vapor retarder can also be an air barrier, but not every good air barrier is a good vapor retarder.
10. Which of the following is defined as "insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings"?
  - a. Polyiso insulation
  - b. Continuous insulation
  - c. Exterior insulation
  - d. Contiguous insulation

### BUILDING ENCLOSURE PERFORMANCE DESIGN

Energy codes require not only energy performance of a building, but also include requirements for vapor retarders and air barriers. These two membranes limit water vapor migration, by affecting different transport methods of that migration. In addition, building codes require water-resistant barriers (WRB's)—which can sometimes be confused with the other guidelines and product lines.



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### Water Resistive Barriers

Water resistive barriers are materials primarily intended to keep liquid water from entering the building enclosure. Commonly, water resistive barriers are specifically designed not to be a vapor retarder. To accomplish this goal the minimum water vapor permeance for a water resistive barrier should be approximately 5 perm, or 300 ng/(Pa•s• m<sup>2</sup>). Water resistive barriers are combined with flashing and other materials to ensure that there are shingled layers within an assembly to direct liquid water to the exterior. Water resistive barriers are designed to be installed on the cold side of the wall cavity insulation but are often positioned on the warm side of continuous insulation. This typical positioning makes it very important to assess their impact on vapor flow and drying potential.

Combined air barriers, vapor retarders and water resistive barriers can be provided in a **single material/product** but, to serve all functions, the position of the product within the assembly must be carefully assessed to perform in harmony with the demands of the environmental conditions. Not all environments can tolerate a single layer serving all of those functions. Toward that end there are also vapor permeable air barriers, and there are water resistive barriers which are not air barriers.

### Vapor Retarders

\*Reader, note that the Air Barrier Association of America (ABAA) website refers to a vapor “retarder” as a vapor “barrier.” ABAA is the national voice of the air barrier industry in America. Typically construction materials do not create an absolute “barrier” against vapor migration. Some amount of vapor gets through. Therefore, perhaps vapor retarder is the more correct term. Therefore it is used here throughout.

Vapor retarders are not to be confused with an air barrier. A vapor retarder is designed to restrict the flow, or vapor diffusion, of water vapor through a material, just the same as an air barrier material restricts the flow of air through a material.

Vapor retarders (or *vapor barriers*) are intended to control the rate of diffusion into a building assembly. Vapor retarders control the rate of moisture flow, or vapor diffusion, where they are placed. Vapor diffusion involves molecules of water vapor traveling through the pore structure of the material. Vapor diffusion is a slow process driven by a difference of vapor

pressure on each side of the material. A vapor retarder limits the rate of vapor migration under a vapor pressure differential. Most vapor retarders are just that—retarders. They do not prevent all diffusion of the water vapor, but slow it substantially.

Because vapor retarders only prevent vapor diffusion through a material their demand for continuity is not the same as is demanded of air barriers. Vapor barriers do not need to be as structural, nor do they need to be as perfectly continuous, as free of holes, as lapped, as sealed, etc. However, reasonable care should still be taken to ensure a high degree of continuity to limit local opportunities for moisture accumulation. For example, a hole in a vapor retarder will simply mean that there will be more vapor diffusion in that area compared to the other areas of the vapor barrier. It is generally true that moisture carried into the assembly via leaking air is a much greater concern than is moisture entering an assembly via diffusion through a small imperfection in the vapor retarder. Mostly importantly the location of the vapor retarding layer relative to the insulation is critical as vapor retarders in the wrong location may result in water vapor condensing on cold surfaces. The rule is that vapor retarders are designed to be installed on the warm side of the insulation.

Water vapor permeance is measured by the amount of water that will work its way through a material. This is normally reported in perm or ng/(Pa•s• m<sup>2</sup>). Many areas require a vapor retarder that has a maximum water transmission rate of approximately 1 perm, or 60 ng/(Pa•s•m<sup>2</sup>).

The increasing use of continuous insulation in enclosure solutions has changed (warmed) the thermal gradient in walls. As such, the potential for condensation has diminished leading to much analysis and discussion on whether vapor retarders should be used at all and if they are used what the water transmission rate should be. Toward that end there is discussion on the need to allow buildings to dry, meaning, if a wall does get wet via leakage or diffusion, then the presence of a vapor retarding layer may be detrimental as it will inhibit drying. Keep in mind that during all this debate, a given design still must meet the local building code, which may demand a vapor retarder even when building science would indicate that they should not be used.

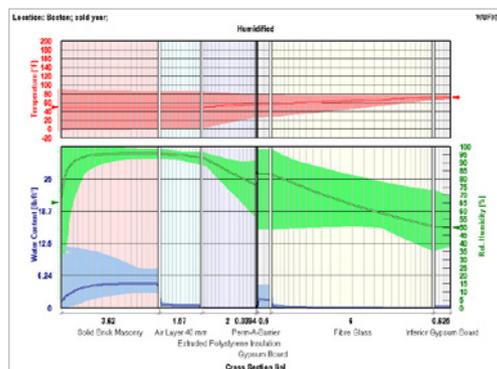
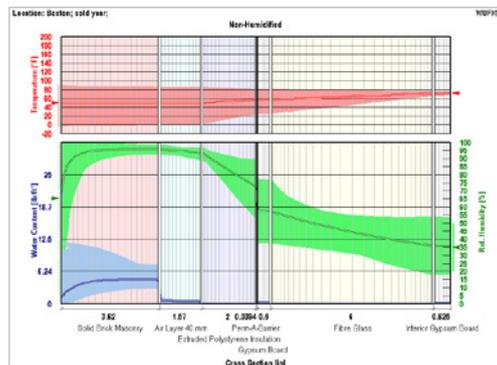
### Air Barriers

Air barriers are designed to minimize air movement to improve energy efficiency, to minimize the transport of airborne contaminants, and, to minimize vapor migration via bulk air transport. This mechanism is driven by a difference in air pressure. Air will flow from areas of high pressure to low pressure. Air pressure differentials are created by many factors, such as wind pressure on a building or positive or negative mechanical pressures. The high pressure air will carry whatever water vapor it contains and mix with the low pressure air, either raising or lowering the overall water vapor content of the air. Think of a hot summer day with high relative humidity outside, compared to a cool low humidity room inside a building. If a window is opened and the wind blows, not only does the temperature of the room increase, but so too does the water vapor and subsequently the relative humidity. Suddenly the comfortable, cool, dry room no longer feels as comfortable, cool or as dry. Because air transport is a macroscopic and quick movement of water vapor, an air barrier must be continuous and tolerant of structural movement. Its location is set more for ease of installation therefore its vapor retarding characteristics must be checked in the design to ensure it is appropriately permeable or non-permeable.

In an effort to be efficient with our designs, we often combine the air barrier and the vapor retarder into one material. Often this material is also our water resistive membrane. The use of one material to perform three of the four functions of the exterior wall (water resistance, vapor retarder, and air barrier) makes the design efficient to construct. However, because one of its functions is the vapor retarder, it needs to be properly located in conjunction with the fourth exterior wall function (thermal resistance) to prevent condensation. The ideal place for this membrane is on the exterior sheathing behind the cladding system with at least some of the continuous insulation to the exterior of it. Additional insulation may, or, may not, be on the inside side of the air barrier in the framing cavity. In either design configuration it is important to view the assembly as a system and verify functionality in its given locale. The energy codes generally state, and it is good practice, that the vapor retarder be located on the winter warm side of the insulation. However, this design principle cannot be

generalized when the air barrier is sandwiched between exterior continuous insulation, and interior framing cavity insulation. Complete system performance must be verified using appropriate modeling software such as WUFI.

To elaborate further, performance modeling of the enclosure solution is important because placing the air barrier behind or between insulation layers may violate two code conditions. First, in hot, humid climates, the air barrier/vapor retarder is on the cold side of the insulation at all times. As a result, water vapor that reaches it from the exterior may condense. However, the seeming violation is not a concern since this membrane is the water barrier as well and since the condensation occurs in the wet cavity, the water is no different than water that gets behind the cladding in a rainstorm. Therefore, although this condition is not per the common prescriptive guidelines in the energy code, it is still an acceptable location.



Computer modeling in a program such as *Warme und Feuchte Instationär* (WUFI) can help to resolve the potential for condensation development.

The second condition where this arrangement violates the code is when designing per the prescriptive R-value approach, which is common. The IECC requires that the exterior wall contain both exterior continuous insulation

in the cavity as well as interior insulation between the studs in framed wall systems, sometimes called a split insulation system. (For mass wall systems, the IECC requires continuous insulation only.) In this instance, the vapor retarder occurs in the middle of the insulation. This may or may not cause condensation issues in the wall system depending on the exterior and interior climates of the building. Computer modeling in a program such as *Warme und Feuchte Instationär* (WUFI) can help to resolve the potential for condensation development. Also note that different interior conditions can result in dramatically different behaviors for the same wall system in the same climate.

For example, consider a building with a masonry cladding, two inch air space, two inches of exterior insulation, an air-vapor-water resisting membrane, exterior sheathing, cold-formed metal studs with six inches of batt insulation, and interior gypsum sheathing. In a cold year for a cold climate city and a non-humidified interior, this wall design is acceptable and does not result in high levels of wall cavity humidity and potential condensation. But if the interior conditions change to a relative humidity of 50 percent (e.g. a museum type environment), then this wall system shows a large buildup of

humidity creating the potential for condensation, which can lead to detrimental effects in the wall system over time.

In situations where energy codes require split insulation, some specifiers choose to follow a prescriptive U-value approach and push all of the insulation to the exterior cavity. While this often solves the condensation potential, it can lead to other issues beyond the scope of this article, such as measures necessary to support cladding through a greater thickness of continuous insulation, maintaining continuity of insulation, and a thicker wall system that requires additional square footage to construct.

### BUILDING ENCLOSURE/ WALL SYSTEMS

Designing the best wall system starts with analyzing the four barriers, especially condensation control. The analysis is critical because blindly following the prescriptive criteria may result in an unsatisfactory building.

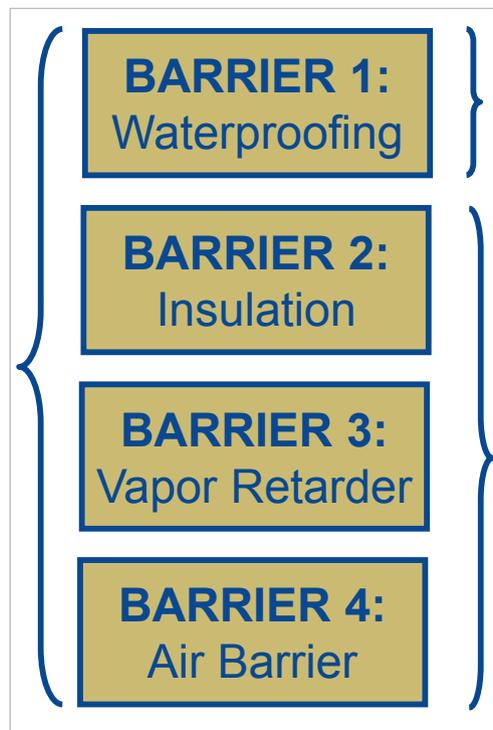
The four barriers are evaluated on the following criteria. Are they reliable, durable, and suitable for use in the way they are proposed to be used? Are they constructible as proposed? Most importantly, **are they continuous?**

They are called the four barriers, but really it's the *four functions* of the exterior envelope of the building:

1. Keeping liquid water out
2. Insulating or providing a thermal barrier around the enclosure
3. Controlling vapor migration
4. Controlling air movement

It may be considered if 4 materials are really needed to perform these 4 functions or tasks. Designers may choose to combine functions into 1 or 2 materials. For example, extruded polystyrene rigid insulation with taped joints can function as a four-barrier material. "Peel-and-stick" self-adhered membranes may serve as a two or as a three-barrier material depending on its permeability. These are all things that the designer should consider from a functionality, cost, and practicality standpoint as much as from a barrier standpoint.

It's important to understand airborne moisture as well as the mechanisms that move it across the enclosure. There is a difference between water vapor moving via *diffusion* and water vapor moving via *mass transport*. An example of diffusion is:



Designing the best wall system starts with analyzing the four barriers, especially condensation control.

Room A at a given temperature has 40-percent relative humidity (RH) and a corresponding amount of vapor pressure. Room B (on the other side of the wall) has a vapor pressure that is less than Room A.

The vapor from Room A will migrate through the wall and go to Room B as the two room pressures are driven to equalize. The vapor will move (permeate) through the pore structure of the wall, which would be more difficult in the presence of a vapor retarder. A vapor retarder has very small pore structure (meaning low permeance), smaller than the molecules of water in the air. Examples are: polyethylene, foil/sheet metal, or oil-based paint.

Conversely, the mass transport of moisture by air is different. Perhaps Room A's air pressure is greater than the air pressure in Room B. If there is a crack or an opening (or breach) in the common wall, air is going to naturally flow from high pressure to low pressure. As the air flows, it takes along any moisture within it. Mass air transport effectively bypasses the diffusion method, rendering a vapor retarder ineffective.

As a result, mass transport is essentially at the macroscopic level. It's clear that the vapor retarder and the air barrier are truly **two different functions and two different things**, but they can be the same material and layer in some cases. A good vapor retarder can also be an air barrier, but not every good air barrier is a good vapor retarder. This is dependent on the material's permeance or pore structure.

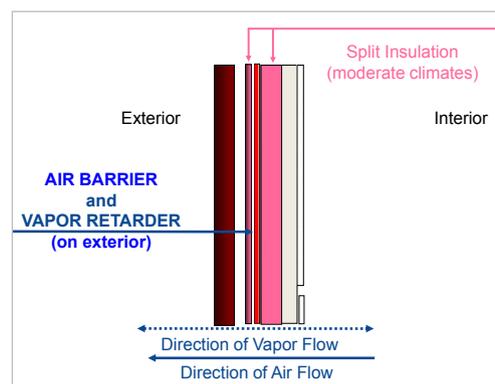
Vapor retarders should be continuous and free of penetrations and leaks, however, they do not have to be perfect. If there's no air-pressure difference between the two rooms and there's a hole in the wall, there's no movement of air. If there is a pressure differential, it's going to eventually diffuse between the two, from 40 percent to 30 percent; and thus both rooms are going to even-out at 35 percent. But this will slowly go through the microstructure. If the walls or the vapor retarder have little holes here and there, it is not crucial.

It is important to differentiate between major breaches in a vapor retarder versus common penetrations as builders put tons of holes in vapor retarders to hold up the claddings and nail down roof sheathings before placing the roofing material. In typical construction vapor retarders are penetrated frequently primarily with fasteners, however, tears, large joints, overlaps, transitions, and MEP penetrations should be neatly fitted and tape sealed.

The location of the vapor retarder is extraordinarily important, which is dependent on interior and exterior climate as well as material properties. Strength isn't an issue, because it does not need to resist differential air pressures. The air barrier, on the other hand, has to be continuous, perfect and sealed well. Any type of breach in it, with any type of air-pressure differential, will lead to air moving through that breach.

But the location of the air barrier in the wall system doesn't really matter. It can be set for ease of detailing, or for some other practical purpose. Depending on where it is located its vapor-permeance may or may not be important particularly if it's intended to be a vapor retarder as well. Of course air barriers must be able to resist air-pressure differential.

When the building is in a hot climate (with a cool interior) and there is insulation only on the interior, the vapor retarder placed outboard of the insulation is in the right location, because the direction of vapor flow is to the interior, and it is blocked. In this case the vapor can't get to the cool spots and thus cannot condense. The airflow also stops at this location. Hot, humid air is not mass-transported to the interior, nor is cooler, conditioned air mass-transported to the exterior. There is no likely condensation issue; these are basics of sound design.



In much of the northern or northeast U.S. there are Florida conditions some days and Arctic conditions other days; it is truly a mixed climate so the designer must accommodate for direction of vapor flow going either way.

Moving north, all the way up through the U.S., different climate zones are encountered. Designing via the prescriptive method of the building and energy code requires splitting insulation layers to bring some insulation to

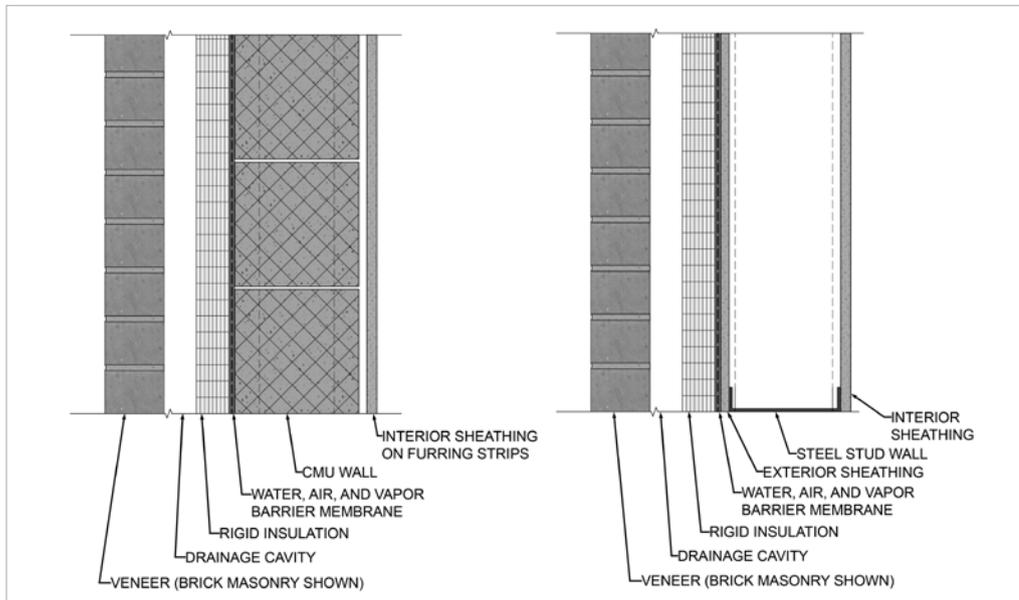
the exterior of the "line in the sand." (The 'line in the sand' meaning that surface location where the design allows for water and vapor accumulation on one side of it, but not the other). As a result, the direction of vapor flow can be in either direction due to the mixed climate. In much of the northern or northeast U.S. there are Florida conditions some days and Arctic conditions other days; it is truly a mixed climate so the designer must accommodate for direction of vapor flow going either way.

Direction of airflow is going to still be primarily to the exterior. Because the interior is probably pressurized, conditioned air must not be lost (lost energy), and when the wind does blow, hot, humid summertime air is not pushed to the interior.

There are several criteria and possibilities based on different climates and zones. Often times a wall system will incorporate a drainage plane or cavity, which serves the purpose of drawing water out and away from the drainage layer.

When the entire insulation R-value is placed fully outboard it is sometimes called the "works everywhere" wall. But it is based on the premise that the air barrier and vapor retarder are not properly designed and placed, and will not function as they should to protect the wall. Essentially insulation, fully outboard, gives the best performance in **every** climate condition because the structural components are fully insulated. As such they are not subjected to potential condensation that may occur when they are in the same plane as insulation and have a temperature differential from one side to the other. However, if the air barrier and vapor retarder layers are properly designed and installed, air/moisture leakage/permeance into the wall is controlled, and this concern is minimal to non-existent. To do this, the prescriptive/performance method within the code must be used, which is essentially the U-value analysis. The graphic below showing brick masonry and CMU, from a moisture management perspective, is essentially the ideal wall, because if a little bit of water gets behind, the CMU won't be affected. The CMU will absorb the moisture, hold it, then release it with time. It's a durable material, as is brick. When designing with metal studs, they are a little less durable, with wood being even less durable.

What this wall shows is continuous insulation only on the exterior of the building. But what exactly is continuous insulation?



The “works everywhere” walls show continuous insulation only on the exterior of the building.

ASHRAE says it’s continuous across fasteners, service openings, installed in the interior or exterior, and integral to any opaque surface of the building envelope.

**Continuous insulation is defined by IECC 2015 / ASHRAE 90.1 / CEC T24 as insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings.**

From the standpoint of a design firm, what does this really mean? If the contractor is only insulating between metal studs or wood

studs, it is not continuous. If installing a metal panel system and using Z-girts or Z-bars to go through the insulation, the reading of the code says that is not continuous insulation anymore, because there are steel Z’s every 16, 24, or 30 inches on-center. That said, over the past several years to capitalize on these new energy trends, new non-metallic girts and clips are becoming more popular such as stud-like structural clips that are made out of fiberglass. These are not a thermal bridge, yet can still be used in attaching metal or fiber cement paneling. In designing structural systems with masonry and other materials, it is critical to allow for as much continuous insulation behind the structural element as possible.

The structural clip systems (to best comply with the definition of continuous insulation in a practical manner) are somewhat expensive, and they are still relatively new to the market. Many people, including designers, have not seen them before, but generally they work. More

and more of them will be installed on buildings, and more code officials will require them as they continue to become educated on the latest requirements of the new and tightening codes.

## SUMMARY

In summary, although enclosure solutions/ systems don’t directly consume energy, they have a lot to do with how the building consumes energy. Building professionals designing complete building performance must take a holistic approach and think about location, siting, lighting, and mechanical designs, and how those all factor into complete building performance. Close collaboration is needed with the other building design professionals to verify that the building performs its best when all these factors are considered. The more we work together on these challenges, the better our buildings will perform.

In addition, building enclosure designers must pay attention to energy and other code requirements that dictate how the building enclosure must perform. Codes provide seemingly simple prescriptive or performance requirements. However, designers must beware not to oversimplify the design process. Without considering specific influences of the building enclosure design, such as exterior and interior climates, material selection, and material placement, enclosures may not perform as intended, resulting in at best higher energy costs and at worst significant reconstruction costs, neither of which satisfies our end clients—building owners. ■