Pushing the envelope to net-zero-energy levels

Often overlooked, the building enclosure plays an integral role in creating ultra-energy-efficient commercial buildings

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Imagine a commercial building that produces as much energy as it needs for its operation. Although the number of net-zero-energy homes being built in the United States is on the rise every year, the idea of scaling that concept to create ultra-energy-efficient commercial buildings may seem impossible.

But net-zero-energy commercial buildings will be a widespread reality in just 20 years.

The Energy Independence and Security Act of 2007 (EISA 2007) calls for all new commercial buildings to be net-zero by 2030. A small number of them already exist in the United States. And the private sector, federal agencies, non-governmental organizations and some of the nations' most prominent building science research labs have come together under the United States Department of Energy's (DOE) Net-Zero Energy Commercial Building Initiative to develop best practices and technologies for achieving ultra-energy-efficient buildings.

Reaching net-zero-energy status requires thoughtful planning, careful design, meticulous construction and responsible operation to maximize energy efficiency before adding renewable energy. A challenge, but one the industry must meet.

Commercial buildings account for almost 40 percent of annual energy use and 40 percent of greenhouse gas emissions in the United States[1]. That makes the impact of America's commercial buildings roughly equivalent to the carbon footprint of India[2].

To create a high-performance structure, the project must be approached from the 'building-as-a-system' perspective and take into account the relationship between the building envelope, electrical load (plug + lighting), mechanical

Structural Insulated Panels (SIPs)

Graphite-enhanced expandable polystyrene

Stucco lath for EIFS

Insulating Concrete Forms (ICFs)

system and the occupants. With net-zero-energy buildings, an additional system—the renewable energy provider—must also be worked into this delicately balanced relationship.

The performance of the building envelope is perhaps the most heavily weighted factor in this relationship. Flaws or weaknesses in the envelope can negate the efficiencies gained through mechanical and lighting upgrades, as well as vastly extend the ROI period on renewable energy systems.

The enclosure is the first, last and only line of defense separating the conditioned interior building space and the exterior elements. It controls heat flow, moisture flow and air flow. It provides structural integrity and protection from rain, snow, hail, wind, dust, pollutants, allergens and pests. . It mitigates street noise and allows us to condition the indoor environment for occupant comfort, and its functionality—or lack thereof—directly impacts the performance of the mechanical system, which accounts for 35 percent of end-use energy consumption in a commercial building.

Design flaws compromise the envelope's ability to perform. For example, most curtainwalls with a mix of vision glass and spandrel panels offer overall R-4 in terms of thermal performance[3] which causes severe strain on the heating system. Daylighting design techniques allow natural light into a building to reduce electrical load, but may allow too much heat to accumulate from solar gain, taxing the air conditioning system.

Construction flaws can sabotage the most efficient design. Uncontrolled air leakage through gaps, cracks and holes in the building envelope means conditioned air escapes and mechanical equipment cannot keep up with the comfort requirements of occupants.

As a result, commissioning the building envelope is a practice that's gaining traction. Functional performance testing is an integral part of the envelope commissioning process and field testing must occur throughout the construction phase because once the enclosure is completed, it may be impossible to access components within it that do not meet performance requirements[4].

Materials selection can also make or break envelope performance. A combination of tried-and-true materials, newly adopted systems and emerging technologies that can meet or exceed performance goals is available today.

Advanced Insulation Materials

Net-zero-energy commercial buildings tend to have thermal performance twice that of their built-to-Code counterparts. Achieving this requires materials that offer higher R-values per inch.

Graphite-enhanced expandable polystyrene (EPS) can increase insulation values by 20 percent over traditional EPS, because the microscopic flakes of graphite act as infrared absorbers and reflectors to lower thermal conductivity. This material can be used for curtain wall, roof deck and interior wall applications, as well as for the insulation component of insulating concrete forms (ICFs) and exterior insulated finishing systems (EIFS).

Closed-cell, spray-applied polyurethane foam (SPF) insulation offers extremely high R-values at 6.7 per inch. Because SPF expands during application to fill every crack and gap and is seamless and self-adhering, it also eliminates convection looping and thermal bridging within the wall system.

Phase-change material for interior wall board allows mass walls to behave as massive walls. This micro-encapsulation technology features plastic capsules filled with a special wax to absorb and release thermal energy by melting and solidifying in a controlled manner. The capsules increase the thermal capacity of building interiors and act to dampen temperature swings, reducing the heating and cooling load.

Vacuum insulated panels (VIPs) consist of a core panel enclosed in a vacuum sealed metallic or Mylar-foil™ envelope, resulting in an insulating value of three to seven times that of equivalent thickness of rigid foam board, foam beads, or fiber blankets. Currently, there are several types of core being developed for this use, including polystyrene, polyurethane, and a combination of silica and carbon.

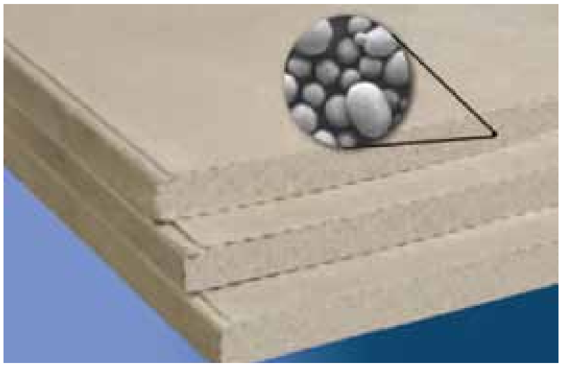
Coupling these high-performance insulation materials with EIFS can vastly improve the thermal performance of a wall to make it net-zero-energy ready. Real-world data demonstrates that EIFS outperform other typical exterior claddings in energy performance, particularly in a hot and humid climate[5].

SPF insulating air barrier

Warm-edge thermoplastic spacer windows

SPF roofing system

Reflective roof coating



Phase-change wall board

Nanotechnology insulating foams, also known as nanofoams, represent the next generation. Researchers are working on ways to transform current standard insulations—such as EPS and polyurethane—into nanofoams. This innovation could significantly reduce heat conduction by 50 percent compared with conventional materials.

Air / Weather Barrier Materials

Air leakage through cracks, gaps and holes in the building envelope, as well as through air permeable materials used in enclosure construction, can waste up to 40 percent of the energy used to heat and cool an average commercial building[6]. Complete air leakage control in the form of a properly installed continuous air barrier system is imperative when designing for net-zero-energy performance levels.

The air permeance of an air barrier material is defined by the Air Barrier Association of America (ABAA) as being no greater than 0.02 L/(s•m^2) @ 75 Pa pressure difference (0.004 cfm/ft2 @ a pressure difference of 1.57 psf or 0.3 inches of water) when tested in accordance with ASTM E 2178[7]. When the continuous system is constructed, the air leakage of the entire air barrier assembly is not to exceed 0.2L/(s•m^2) @ 75Pa. (0.04 cfm/ft^2 @ 1.57 psf)[8].

One-component, fluid-applied vapor permeable air/ water-resistive barriers are resilient, waterproof coatings that may be roller-, brush-, trowel-, or spray-applied directly to approved wall substrates. Offering an air permeance rating of 0.0049 l/s.m^2 @ 75 Pa, the liquid application helps to reduce installation error by eliminating the seams, lap joints and staples that can adversely affect air barrier continuity.

Closed-cell SPF insulating air barrier materials offer an air permeance rating of 0.000025 l/s.m^2 @ 75 Pa (at 0.5-inch thickness), along with increased rack and shear resistance, vapor impermeability and insulation values of R-6.7 per inch. This allows SPF to perform triple duty—insulation, air barrier and vapor barrier—in a single application.

Fenestration

Fenestration is often the weak link in the enclosure. Careful consideration must be given to the proportion and position of windows to strike a balance between the positive effects of daylighting and the negative effects of solar gain and low thermal performance.

Low-e windows featuring warm edge thermoplastic spacer (TPS) technology function as a thermal break, reducing the transfer of heat between conductive materials by sealing the edges of gas-filled insulated glazing units. Warm edge TPS technology can improve the energy performance of a window unit by up to 10 percent.

Exterior and garage doors must be as well insulated as possible when the goal is a net-zero-energy building. Cores made with rigid polyurethane foam offer insulation R-values of 6.7 per inch.

Roofing

Cool roofing technologies, such as light-colored coatings, can reduce the amount of heat absorbed at the roof level, limiting air conditioning needs and aiding in the reduction of urban heat island effect.

Near Infrared (NIR) reflective pigments help optimize the performance of cool roof coatings while allowing aesthetic freedom. Transparent NIR pigments can be formulated to reflect up to 45 percent of solar radiation, while black NIR pigments have solar reflectance of as much as 30 percent. The lower absorption of black NIR black pigment relative to other black pigments results in a temperature decrease as much as 68 degrees Fahrenheit (20 degrees Celsius) on building surfaces.

Medium- and high-density SPF roofing systems offer the same insulation values as their insulation and air barrier counterparts at 6.7 per inch, coupled with industry-leading durability and severe weather resistance. When combined with reflective elastomeric coatings—required to protect the polyurethane from UV damage—these systems can pay for themselves through energy savings in an average of 4.5 years for a retrofit application[9].

SPF systems are also highly compatible with rooftop photovoltaic renewable energy systems because they are custom sloped and can be renewed indefinitely with simple recoats, reducing the risk of damage to the solar equipment during re-roofing.

Structural Components

Wall technologies such as structural insulated panels (SIPs) and insulating concrete forms (ICFs) are among the most common envelope solutions for net-zero-energy homes and are also suitable for light commercial construction.

SIPs consist of pre-fabricated panels of insulation sandwiched between structural skins and may be used for wall and roof applications. ICFs consist of two insulation forms erected at the job site that then have the gap between forms filled with concrete (and often rebar) for structural strength.

Insulation options for SIPs and ICFs include rigid polyurethane (R-6.7 per inch), EPS (R-3.5 per inch) and graphite-enhanced EPS (R-4.5 per inch), allowing these structural systems to offer thermal performance values of R-50 or more.

Today's Technologies for Tomorrow's Buildings

The quest to achieve net-zero-energy commercial buildings is underway, and the role of the building enclosure will gain increasing emphasis.

Integrated design practices, careful materials selection and ongoing commissioning throughout construction will uncover best-practices that will speed the path toward making ultra-energy-efficient buildings commonplace.

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1 *Annual Energy Review 2008*, Energy Information Administration, http://www.eia.doe.gov/aer/pdf/aer.pdf

2 *Absolute Zero: Net Zero Energy commercial buildings – an inspiring vision for today*, Clay Nesler and Anne Shudy Palmer, Johnson Controls, 2009

3 *Can Highly Glazed Building Façades Be Green?* John Straube, Ph.D., P.Eng., Building Science Corporation, 2008

4 *Functional Performance Testing Within the Building Envelope Commissioning Process*, Kevin D. Knight, John A. Runkle, Bryan J. Boyle, Building Enclosure Science and Technology Conference, 2010

5 *Exterior Wall Cladding Performance Study*, Oak Ridge National Laboratory/EIFS Industry Members Association, 2008

6 *Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use*, Steven J. Emmerich, Timothy P. McDowell and Wagdy Anis, National Institute of Standards and Technology, 2005

7 http://www.airbarrier.org/materials/index_e.php

8 http://www.airbarrier.org/materials/assemblies_e.php

9 *Texas A&M University Energy Data Measuring Cost Saving of Campus SPF Roofs Compared with BUR Roofs*, Gerald Scott, P.E., 1985

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BASF is committed to technology transfer throughout the North American construction market.

Our Better Home, Better Planet initiative helps homebuilders big and small learn about the systems, technologies and best-practices that go into building a net-zero energy home—and helps them plan, build and promote their first attempt.

Our BASF Online Campus for High-Performance Construction offers design professionals access to registered continuing education courses 24 hours a day, seven days a week. Our newly formed Center for Building Expertise is designed to be a resource to help design professionals, building owners and facility managers improve the performance of their buildings. The goal? Accelerate the technical and financial feasibility of net-zero energy commercial and educational buildings.

Our NEED™ (Neighborhood Energy Efficiency Drive) program even educates BASF employees across the United States about ways they can improve the energy efficiencies of their own homes.

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