EIFS and Sustainable Design

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As the sustainable design movement continues to gain momentum around the globe, many design/construction professionals are still trying to sift through what it means to be green. According to the World Commission on Environment and Development (WCED), "sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs."

The U.S. Office of the Federal Environmental Executive (OFEE) is more specific. It refers to "the practice of (1) increasing the efficiency with which buildings and their sites use energy, water, and materials, and (2) reducing building impacts on human health and the environment through better siting, design, construction, operation, maintenance, and removal—the complete building lifecycle."[1]

The Construction Specifications Institute (CSI) recently voted to adopt the Architecture 2030 Challenge and 2010 Imperative, two initiatives aimed at climate change. The former plans to reduce the use of fossil fuels in buildings by 60 percent in 2010, 70 percent in 2015, 80 percent in 2020, 90 percent in 2025, and to achieve full carbon neutrality by 2030.[2] The latter proposes ecological literacy in design education and carbon-neutral design school campuses. Both these projects have widespread industry support, an indicator of how important the issue of sustainability has become to professionals working in the built environment.

Keeping such objectives in mind, one understands why it is important to consider the attributes of building materials in terms of their environmental impact. Exterior insulation and finish systems (EIFS) can be a boon for commercial buildings or multi-family projects (along with single-family residences), as an EIFS wall can economically provide energy efficiency and reduced CO_2 emission levels. However, without durability as the cornerstone of sustainable design, most other sustainable attributes of products or systems are lost. Fortunately, EIFS also offer long-term performance and durability. (As with virtually all building materials, proper installation and integration into construction are essential.)

Environmental design

From an architectural perspective, EIFS offer the ability to replicate almost any architectural style or finish material, coming in a variety of shapes, colors, and textures. They are low in cost and lightweight, providing an economical cladding system. They can also be installed over existing buildings, allowing design/construction teams to keep the existing building shell. (This can be a way for projects to earn points under environmental rating programs.)

An example can be found in a recent repair of university dormitories in Atlanta, Georgia, where an existing stucco cladding was re-clad with EIFS. Primary issues with the wall assembly were leaky windows, as well as thermal bridging of metal studs that caused 'ghosting' on the interior, along with mold on some stud lines. Concerned not only with the possible effects on indoor air quality (IAQ) and occupant health, but also with the

wall assembly’s long-term durability, the university’s engineers decided to re-skin with EIFS. Insulation was adhesively attached to the existing stucco finish. The exterior insulation corrected the thermal bridging issue, while the leaky windows were removed and properly flashed to make them drain to the exterior, rather than into the wall.
From a building science perspective, the overall energy performance of a building and its interior environment can be greatly improved by placing the insulation on the outside of the building. This strategy minimizes thermal bridging and helps keep the structural members at a consistent temperature, improving their expected longevity.
By keeping the temperature of structural members constant, they are less susceptible to the movement and stress caused by temperature swings that could lead to cracking in concrete, masonry, and stucco walls. (In turn, this cracking could lead to water penetration and degradation, such as spalls or corrosion.)

Additionally, with sufficient insulation outboard of the structure, a dewpoint is eliminated and the potential for condensation from vapor diffusion is minimized. Mold, rusting of metal fasteners and metal framing members, and deterioration of batt insulation and its R-value are a few of the potential effects of condensation that can be avoided.

Traditional EIFS

Traditional EIFS have typically consisted of five components:

- an insulation board (see “Insulation Boards,” page 9);
- an adhesive and/or mechanical fastener to attach the insulation board to a substrate;
- reinforcing mesh for impact resistance;
- a base coat to embed the reinforcing mesh and provide weather resistance; and
- a decorative and protective finish coat.

While traditional or face-sealed EIFS were associated with some of the water intrusion issues that have plagued the residential construction industry for the past 30 years, the materials themselves were not the root cause. As buildings were made tighter and more energy-efficient, they became somewhat less forgiving of poor workmanship and water damage became more frequent.

Windows (and their installation) have also been a source of leakage into walls. This, combined with poor construction practices and tighter building envelopes, can affect durability, regardless of the cladding—brick, stone, EIFS, concrete, wood, or vinyl siding.

New generation of EIFS

In response to the water intrusion issues, building wraps or asphalt-impregnated sheathing paper and felts were installed behind the EIFS to provide moisture protection to the wall structure. These wraps are relied on for providing water resistance, but they are often punctured and/or have the potential for tearing and mislapping during installation. As they are not fully adhered, they are also susceptible to billowing under wind load, which affects the wall’s pressure equalization performance. Further, where sheathing paper, felt, or building wraps are used, mechanical attachment of the EIFS becomes necessary (EIFS adhesives will not stick to sheet goods). Mechanical fasteners render EIFS less thermally effective, as the fasteners create thermal bridges. (The fasteners can cause ‘ghosting’ through the finished wall surface.)
Newer EIFS products can overcome the limitations of traditional moisture protection and mechanical fasteners. These materials incorporate a fluid-applied waterproofing membrane and air barrier directly applied to the sheathing behind the EIFS wall covering

(Figure 1, page 3). Rather than simply a cladding, these systems can be considered a complete exterior wall assembly, providing multiple building envelope functions.

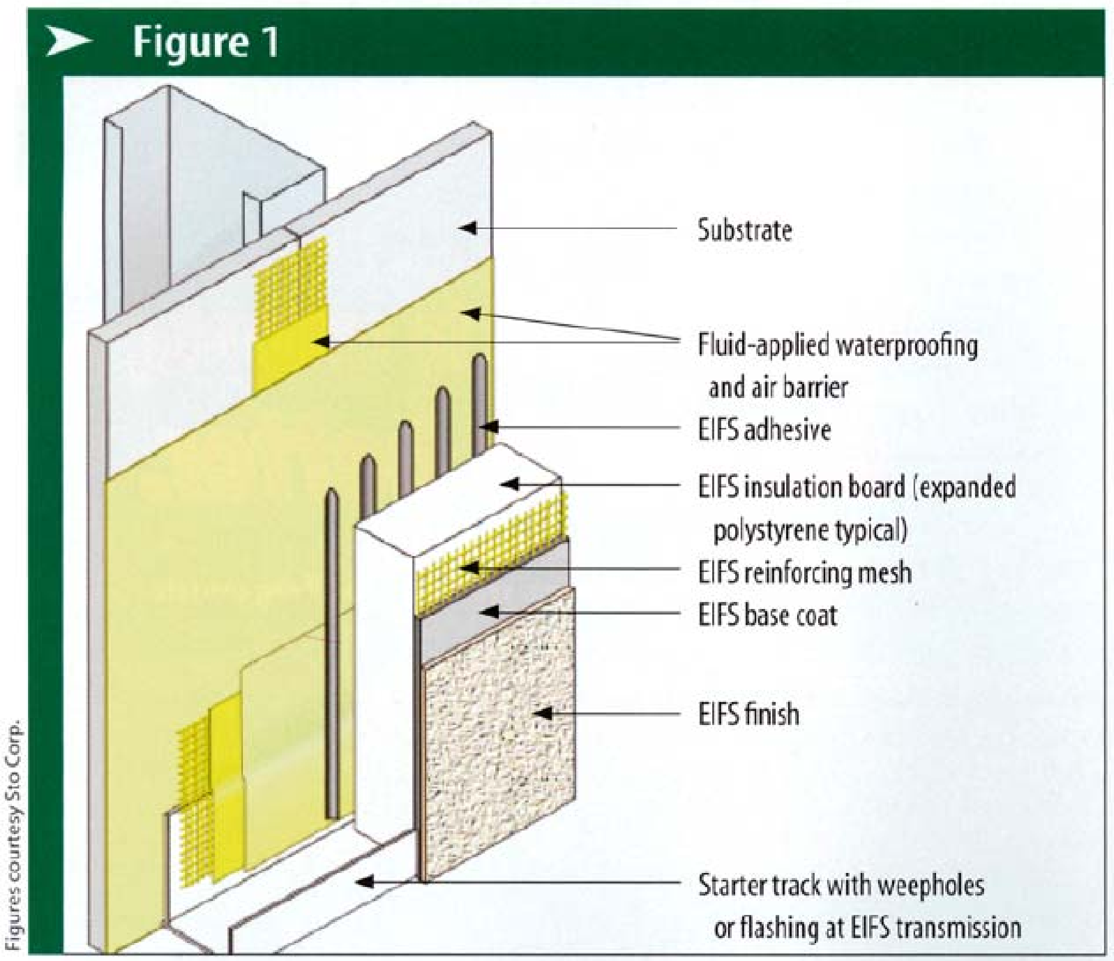


Figure 1

Weather barrier
Most exterior wall problems are caused by water, primarily rain penetration. When water gets into the wall system and wets the assembly's materials, it can accelerate deterioration of those materials and create conditions conducive to mold growth (a less than sustainable condition). Durability can be drastically improved if the wall is designed to prohibit rainwater penetration. This is why a wall requires a weather barrier—to act as the initial defense against water penetration, by shedding rain off its surface. In an EIFS wall, the lamina (*i.e.* base coat, mesh, and finish coat) provides this function. In addition, any joints in the exterior wall system, such as those between dissimilar materials, must be designed to resist rain penetration. Joints and flashing should be designed and constructed to slope toward the outside of the wall to prevent gravity flow of water inwards. Where appropriate, two-stage joints, drip edges, and capillary breaks should be incorporated to avoid inward water movement.

Water-resistive barrier
Incorporating a secondary means of controlling rainwater penetration (*i.e.* moisture or water-resistive barrier) can be beneficial to prevent damage during construction and to keep the building interior dry even before the cladding (*i.e.* weather barrier) is installed.

In the case of some newer EIFS styles, it is the fluid-applied waterproofing applied to the substrate that serves as the water-resistive barrier. When water gets past the EIFS lamina and insulation, it is stopped by the waterproofing.

These newer EIFS products also provide an air cavity behind the insulation. Exactly how this is accomplished is usually part of the proprietary nature of the EIFS, and may involve the use of slots cut into the insulation or vertical ribbons of adhesive. Regardless, these air cavities provide a drainage space; in the event water gets through the outer surface of the EIFS (*i.e.* weather barrier) at a crack, water flows downward via gravity. Flashings installed strategically at floor lines and at the base of the wall direct the water back outside the wall where it cannot damage internal wall components.

The incorporation of a water-resistive barrier in EIFS improves the long-term durability of the wall system by minimizing the possibility of moisture damage to the water-sensitive elements in the wall.

Thermal barrier

By incorporating a thermal barrier within the building envelope, it is possible to minimize the flow of heat between the inside and the outside, allowing interior conditions to be maintained at a comfortable temperature.

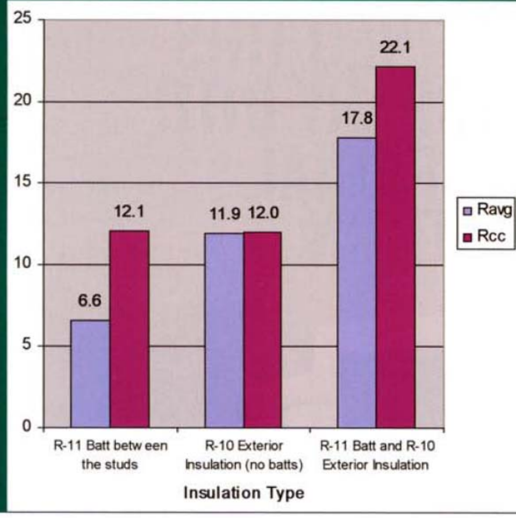
In conventional frame wall construction, batt insulation is placed within the stud space to provide the thermal barrier. Improved thermal resistance is achieved by increasing the studs' thickness, allowing thicker insulation to be used. However, as the studs are exposed to both the inside and outside environments, they conduct heat at a much higher rate than the insulation, creating multiple thermal bridges, and reducing the thermal barrier's overall effectiveness.

As the first two letters in the EIFS acronym suggests, the insulation is applied to the exterior of the building frame, virtually eliminating the multiple thermal bridges. A recent study by Pennsylvania Housing Research Center (PHRC) shows significant reductions in center-of-cavity R-value for steel-framed wall assemblies, reducing it by as much as 56 percent when a framing factor (*i.e.* thermal bridging) is taken into account to measure R-value.[3] The only practical way to negate the effects of thermal bridging caused by steel studs is to place insulation outboard the studs.

For example, an R-11 (1.94 $k \bullet m^2/W$) batt-insulated steel frame wall assembly is effectively R-6.6 (1.16 $k \bullet m^2/W$) (R_{avg}), a 45 percent reduction in the center-of-cavity R-value (R_{cc}) which results in only a 55 percent thermal efficiency (R_{avg}/R_{cc}). Yet, when the same assembly has the batt insulation removed and R-10 (1.76 $k \bullet m^2/W$) exterior insulation added (slightly more than 64 mm [2.5 in.] of expanded polystyrene [EPS] insulation), the effective R-value is almost equivalent to the center-of-cavity R-value of the batt-insulated assembly, and the thermal efficiency is 99 percent. When batt insulation and exterior insulation are combined, the effective R-value of 17.8 (3.13 $k \bullet m^2/W$) and thermal efficiency of 81 percent are significant performance improvements to the assembly with only batt insulation. The improvement in effective R-value performance through the use of exterior insulation is clearly demonstrated in Figure 2 (page 5).

Exterior Insulation Influence on Thermal Efficiency and R-value

Figure 2



1. Data source: PHRC Report No. 58.
2. Base wall assembly: 2x4 steel studs @ 400 mm (16" oc) w 13 mm (½") gypsum board interior and 13 mm (½") plywood sheathing exterior.
3. R_{cc} = center-of-cavity R-value.
4. R_{avg} = average R-value when studs are factored into measurement of R-value.
5. Thermal efficiency = R_{avg}/R_{cc}.
6. Contribution of any cladding or surface air films not included in R-value.

Further, the thickness of the insulation in EIFS can be significantly increased to make even more dramatic increases to the R-value and the thermal efficiency of the wall. (For a particularly sustainable example, see “Waldsee BioHaus,” page 10.) For design professionals serious about the 2030 Challenge, the reduction of CO_2 emissions through exterior insulation is an available, economical solution that can have an immediate positive impact.

Air barrier

Air barriers have been required by the *National Building Code of Canada (NBC)* since 1985. More recently, some states (*e.g.* Massachusetts, Minnesota, Michigan, and Wisconsin) have added similar requirements. In these colder climates, preventing air leakage through the building envelope helps prevent the exfiltration of heated air to the cold exterior and the infiltration of cold, untreated air to the interior. The result is a much more thermally controlled environment requiring less energy input to maintain.

A study conducted by the National Institute of Standards and Technology (NIST) investigated the energy savings attainable through the installation of an air barrier capable of achieving a maximum air leakage rate of 1.2 L/s-m^2 (0.24 cfm/sf) at a pressure difference of 50 Pa (1 psf) between the inside and outside. Based on simulations of several different building types in five cities representative of different U.S. climate zones, NIST determined an air barrier can achieve an annual heating and cooling energy cost savings of as much as 36 percent, with the highest savings in the heating-dominated climates.[4]

Further, stopping air leakage prevents the second most common source of moisture in a wall assembly—condensation. In a cold climate, as warm humid air from inside the building moves through the envelope, the air cools until it is no longer able to hold its moisture. The moisture condenses on the first cold surface within the wall assembly below the dewpoint of the air (often the back of the exterior sheathing).

In a hot climate, the movement of humid air is typically from the outside to the inside, but with the same potential effect—condensation within the wall assembly, usually on the back of the interior gypsum wallboard. Studies by the Oak Ridge National Laboratories (ORNL) and the National Research Council of Canada’s Institute for Research in Construction (NRC-IRC) have shown controlling airflow through the building envelope is more important and effective in reducing moisture transport than controlling vapor diffusion. Additionally, it improves the building's energy efficiency and air quality (thus, the importance of an air barrier).[5]

A structural, durable, continuous, and air-impermeable barrier throughout the building envelope can prevent air movement across the envelope. The fluid-applied membrane of some newer EIFS assemblies meets all these requirements. Being fluid-applied makes certain any joints or gaps are filled, helping to ensure continuity. Where necessary, compatible sheet materials or spray foams can bridge larger gaps between different materials within the wall (*e.g.* junctions with windows or doors). As it is fully adhered to the substrate, the fluid-applied membrane becomes an integral part of it, assuming the strength of the substrate and the ability to resist pressure differences caused by wind, stack effect, or mechanical systems. The membrane is located on the interior side of the insulation in an EIFS wall, so it is protected from the exterior elements, helping to ensure longevity.

Avoiding the double vapor barrier

For conventional frame wall construction in a cold climate, a polyethylene vapor barrier is typically installed behind the interior gypsum wallboard. Alternatively, special vapor barrier paint may be applied to the drywall surface. The concern of some architects is the air barrier/waterproofing membrane in some newer EIFS assemblies could also function as a vapor barrier, creating a double vapor barrier situation. While this is may be a problem with some waterproofing and air barrier materials, the products used in EIFS are generally vapor-permeable and thus permit vapor diffusion and drying. (It is always important for the design professional to discuss system properties with its manufacturer.)

The accepted definition of a vapor-retarding material (vapor barrier) is one that has a water vapor permeance of 57.4 ng/(Pa•s•m^2) or 1 perm. A 0.1-mm (4-mil) polyethylene product has a vapor permeance of 4.6 ng/(Pa•s•m^2) or 0.08 perms, and No. 15 building felt has a vapor permeance of about 325 ng/(Pa•s•m^2) or 5.7 perms. Some EIFS water-resistive barriers have a vapor permeance equivalent to building felt, while others can be slightly higher or lower, depending on the manufacturer. As long as the EIFS water-resistive barrier has vapor permeability significantly higher than does the interior vapor retarder, the 'double vapor barrier' does not exist. Consequently, it should not be a concern in a cold climate, provided bulk water is kept out of the stud cavity (which should always be the case in any durable wall design).

In hot humid climates, the predominant water vapor diffusion direction is from the humid outside environment toward the cooler, dryer, air-conditioned interior environment. A vapor retarder should not be placed on the interior of the batt insulation in such climates; rather, such walls should be allowed to dry to the interior.

EIFS and VOCs

In addition to providing all important exterior wall requirements (*i.e.* weather barrier, water-resistive barrier, air barrier, thermal barrier), the components in many EIFS assemblies have quite low levels of volatile organic compounds (VOCs), particularly in comparison with many wood preservatives, primers/sealers, concrete curing compounds, pool coatings, and lacquers. The water-resistive barrier, adhesive, base coats, and finish coats typically comply with local, state, and national requirements (Figure 3, page 7). Again, it is important to consult with the manufacturer, along with the authority having jurisdiction (AHJ).

Figure 3 — EIFS Components and VOC Compliance

Component	Maximum Allowable VOC (g/L) EPA[1]	Green Seal Standards GS-11 and GS-36	SCAQMD[2] Rule 1113	SCAQMD Rule 1113 (effective July 1, 2008)	Typical VOC of EIFS Component
Water-resistive Barrier: Fluid-applied Waterproofing/Air Barrier Material (Sealer)	400	N/A	100	100	<100
EIFS Adhesive	250	250	100	50	<50
EIFS Base Coat	250	100	100	50	<50
EIFS Primer (optional)	350	100	100	100	<75
EIFS Finish	250	100	100	50	<50

[1] EPA: Environmental Protection Agency
[2] SCAQMD: South Coast Air Quality Management District

When a product is 'low VOC,' it has a limited amount of volatiles and a minute quantity of carbon-based material is emitted into the air as it is applied and dries. Low VOC products not only have minimal effects on air quality (particularly important in confined spaces), but also have minimal impact on the environment by virtue of the low carbon-based emissions.[6]

Conclusion

Exterior insulation and finish systems contribute to sustainable design in several ways:

- longevity and lifecycle analysis;
- reuse of existing building shells;
- optimization of energy performance;
- reduced carbon emissions; and
- low VOC components for improved air quality and reduced carbon emissions.

Further, as illustrated throughout this article, EIFS assemblies can be multifunctional and highly effective systems. As demonstrated by the effective R-value (R_{avg}) of these systems and the moisture protection they provide, EIFS can be an important component of an overall sustainable design strategy effective in achieving building envelope and operating efficiency.

Notes

[1] See WCED's *Our Common Future,* (Oxford University Press, 1987) and OFEE's "The Federal Commitment to Green Building: Experiences and Expectations" from 2003.
[2] See "Conference of Mayors Pushes for More Efficient Buildings," in the 12 June, 2006 edition of *Facilities Net News.*
[3] See Robert Bombino and Eric Burnett's *Design Issues with Steel-stud-framed Wall Systems* (PHRC Research Report Series 58, May 1999).
[4] See Steven J. Emmerich, Tim McDowell, and Wagdy Anis' *Investigation of the Impact of Commercial Building Envelope Airtightness on HVAC Energy Use* (NISTIR 7326, 2006). Visit fire.nist.gov/bfrlpubs/build05/PDF/b05007.pdf for the full report.
[5] See "Air Sealing," a November 1999 U.S. Department of Energy Technology Fact Sheet written by ORNL and the Southface Energy Institute (SEI). See also Neil B. Hutcheon and Gustav Handegord's *Building Design for a Cold Climate* (NRC-IRC, 1989), along with NRC-IRC's *Canadian Building Digests* (volumes 1-100, 101-150, and 151-200).

[6] EIFS components are usually applied outside, but the Environmental Protection Agency (EPA), South Coast Air Quality Management District (SCAQMD), and the Green Seal program all have established VOC limits for not only interior, but also exterior coatings. The importance of a low-VOC product on the exterior is not only the health and safety of the applicators (these coatings may be installed in tented spaces), but also the low carbon dioxide emissions.

Additional Information

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Insulation Boards

The insulation board can be one of the most important components of the exterior insulation and finish system (EIFS). The most common type of board used is nominal 16.0 kg/m^3 (1 pcf) Type I expanded polystyrene (EPS) with an R-value of 3.60 (0.63 K•m^2/W) per 25.4 mm (1 in.) of thickness. In some systems, nominal 32.0 kg/m^3 (2 pcf) Type IV extruded polystyrene (XPS) is used with an R-value of 5.00 (0.88 K•m^2/W) per inch (25.4 mm) of thickness. Both boards conform to ASTM International C 578, *Specification for Rigid, Cellular Polystyrene Thermal Insulation.*

Recently, a separate standard, ASTM E 2430, *Specification for Expanded Polystyrene Thermal Insulation Boards for Use in Exterior Insulation and Finish Systems,* was produced by ASTM Committee E06 on Building Performance. While EPS is a combustible building material, it is approved for use on noncombustible-type construction without setback or height limitations provided certain requirements are met. These requirements involve material tests for surface burning, and assembly tests to evaluate flammability, ignition, and fire resistance. Individual manufacturer's building code compliance reports should always be checked for use and limitations of their EIFS products.

EPS does not contain any ozone-depleting chemicals or expanding agents (*e.g.* [CFCs], [HCFCs] or [HFCs]). Since it does not degrade, rot, or dissolve in water or soil, it will not contaminate the environment if used in a landfill. The main environmental issue with EPS is litter and disposal which must be addressed at the job site through proper controls by the contractor during installation.

EPS waste can be recycled and re-used as foam cushioning, protective packaging, in lightweight concrete products, and in other polystyrene applications at the end of its life span. The EPS industry has a recycling association that can assist in efforts to recycle in locations where this option exits. Where recycling is not an option, EPS can be safely incinerated at government waste-to-energy systems since it burns cleanly and produces no toxic ash.*

* See “EPS Board: Environmental Impact and Management and Disposal of Waste Material,” an EIFS Industry Members Association (EIMA) Tech Note No. C-100 (June, 1993). Also, visit EPS Recycling International at www.epsrecycling.org/pages/home.html.

The Waldsee BioHaus

In 1961, the Concordia Language Villages were established in Bemidji, Minnesota. The campus offers language and cultural immersion programs to students from across the United States. The newest addition to Waldsee (the German language ‘village’) is the two-story, 465-m^2 (5000-sf) BioHaus. It marks the first building in the United States to be certified under the German PassivHaus standard—believed by many international sustainability experts to be the world’s leading criteria in energy-efficient construction. (It significantly surpasses the energy criteria for the U.S. Green Building Council’s [USGBC’s] Leadership in Energy and Environment Design (LEED) program.)

The project was funded in part by the Deutsche Bundesstiftung Umwelt (DBU), the world’s largest foundation dedicated to environmental practice, education, and construction. It is the first time the foundation has awarded such a grant in North America.

The BioHaus uses 85 percent less energy than comparable U.S. buildings, showcasing new approaches to energy conservation and sustainable building design. Strategies included specifying low-emission, environmentally responsible building products, materials, and chemicals, along with heat recovery, air exchange systems, and high-quality windows and doors.

For the building envelope, architect Stephan Tanner of Intep LLC, selected vacuum-insulated panels for the second floor and an exterior insulation and finish systems (EIFS) product for the first floor, demonstrating the sustainable nature of these systems. The R-value of above-grade walls is R-70. This is achieved through a combination of EIFS and between-the-stud (2x12 studs) icynene spray insulation on the first floor.

To receive certification as a PassivHaus, a building must undergo physical testing as verification it has met the required targets. The results from the BioHaus, and the corresponding PassivHaus requirements, are shown below:

BioHaus and PassivHaus		
	Waldsee BioHaus Results	**PassivHaus Requirement**
Annual Specific Space Heating Energy Requirement	13.7 kWh/m² (4350 Btu/sf)	<15 kWh/m² (<4760 Btu/sf)
Airtightness at 50 Pa (1.0 psf) pressure difference	0.18 ach*	<0.6 ach

*ach = air changes per hour

The BioHaus achieved these results mainly through its insulation, elimination of thermal bridging, and airtightness. While it may be financially impractical for all structures to meet this level of performance, significant strides can be made toward achieving sustainable buildings through research and consultation with manufacturers. While not all EIFS are created equal, the system can generally be considered environmentally responsible through its practical use of exterior insulation, reduction of thermal bridging, and increased airtightness.