FACTS | Foam Plastic Applications for Better Building

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Passive House Construction
An Ideal Multifunctional Application of FPIS ci

Credit: Beamie Young/NIST

Credit: DuPont/Monte French Design Studio

What is Passive House Construction?

Passive House Construction strives to smartly address low energy (or net zero energy) construction by focusing first on reducing the energy demand of a building. It is a unique construction method because its primary focus is on the "passive" features of a building's energy systems, those that silently deliver a high level of performance over the entire life of a home without any special attention. In other words, for a one-time initial investment in key passive features, occupants enjoy a lifetime of performance and value through building durability, comfort, and energy savings.

■ What are the key "passive" features of a building?

Passive features of a building are those that deliver value and inherent performance simply by being built into the structure from the start. They work 24/7/365 without any need for power, control, maintenance, or replacement. The three key features of passive construction are:

1. A well-insulated building envelope (roofs, walls, floors, and foundations)
2. High performance fenestration (windows and doors)
3. An air-tight building enclosure (coupled with heat-recovery fresh air ventilation)

NOTE: The "active" features of a home include systems such as HVAC equipment (e.g., gas furnace or heat pump and ventilation systems) and renewable energy systems (e.g., rooftop PV panels), if used. Such systems actively use, transform, or produce energy and require more frequent maintenance and replacement than passive features. Also, their sizing and effectiveness depends on the passive features of a building.

■ What are some benefits of passive construction?

1. Lower energy use and increased energy cost savings
2. Improved occupant comfort and productivity
3. Greater resiliency of living conditions for occupant protection during severe winter and summer temperature events
4. Smaller HVAC equipment and fewer units than required in typical construction
5. With proper construction practices, greater durability and protection of the structure

■ How can FPIS ci help optimize Passive House Construction?

The multifunctional capabilities of FPIS ci are particularly suited to achieving passive house construction goals. As shown in Figure 1, FPIS ci can be used to create an effective continuous environmental barrier around the entire shell of a structure (foundation to roof). As a result, many important design, construction, and performance benefits may be optimally realized with FPIS ci:

1. **Continuous Insulation** – FPIS ci provides for optimized thermal performance and energy savings by reducing the impacts of thermal bridging. It also delivers sustainability with significant total carbon emission savings.
2. **High R-value** – FPIS ci is a high R-value insulation material resulting in less volume/weight and reduced assembly thicknesses, while achieving a high level of thermal performance required for passive house construction.
3. **Water Resistance** – Mismanagement of rainwater is one of the main destroyers of building durability and performance, particularly in wet/rainy climates. FPIS ci materials are inherently water-resistant (do not rot or corrode) and can provide a robust water-resistive barrier (WRB) system for building exterior walls, which helps protect the structure from water intrusion and damage. It also integrates well with window installation and flashing for water-resistance and optimized thermal performance at the window-wall interface.
4. **Water Vapor Control** – Protecting a structure from the harmful effects of water vapor diffusion (e.g., condensation or material water accumulation by adsorption) is important in all climates. FPIS ci is a robust and code-compliant means to address water vapor by controlling seasonal vapor flows and internal assembly temperatures in a way that minimizes vapor diffusion wetting potential and provides optimized drying in all climates with appropriate vapor retarder specification. For more guidance on control of water vapor using FPIS ci, refer to the free Thermal/Moisture Calculators for Steel Frame Walls and Wood Frame Walls, and the Water Vapor Control resource page, which features a QuickGuide that addresses the three steps for code-compliant use of water vapor retarders and FPIS ci.
5. **Air Barrier** – Most FPIS ci materials at commonly used thicknesses are code-compliant air barrier materials and can be used as an air barrier assembly with joints sealed (same as required for WRB applications in #3 above). An FPIS ci air barrier on the exterior, coupled with an interior air barrier (e.g., air-barrier drywall installation), can provide optimal assembly performance for compliance with the stringent air leakage requirements of passive house construction.

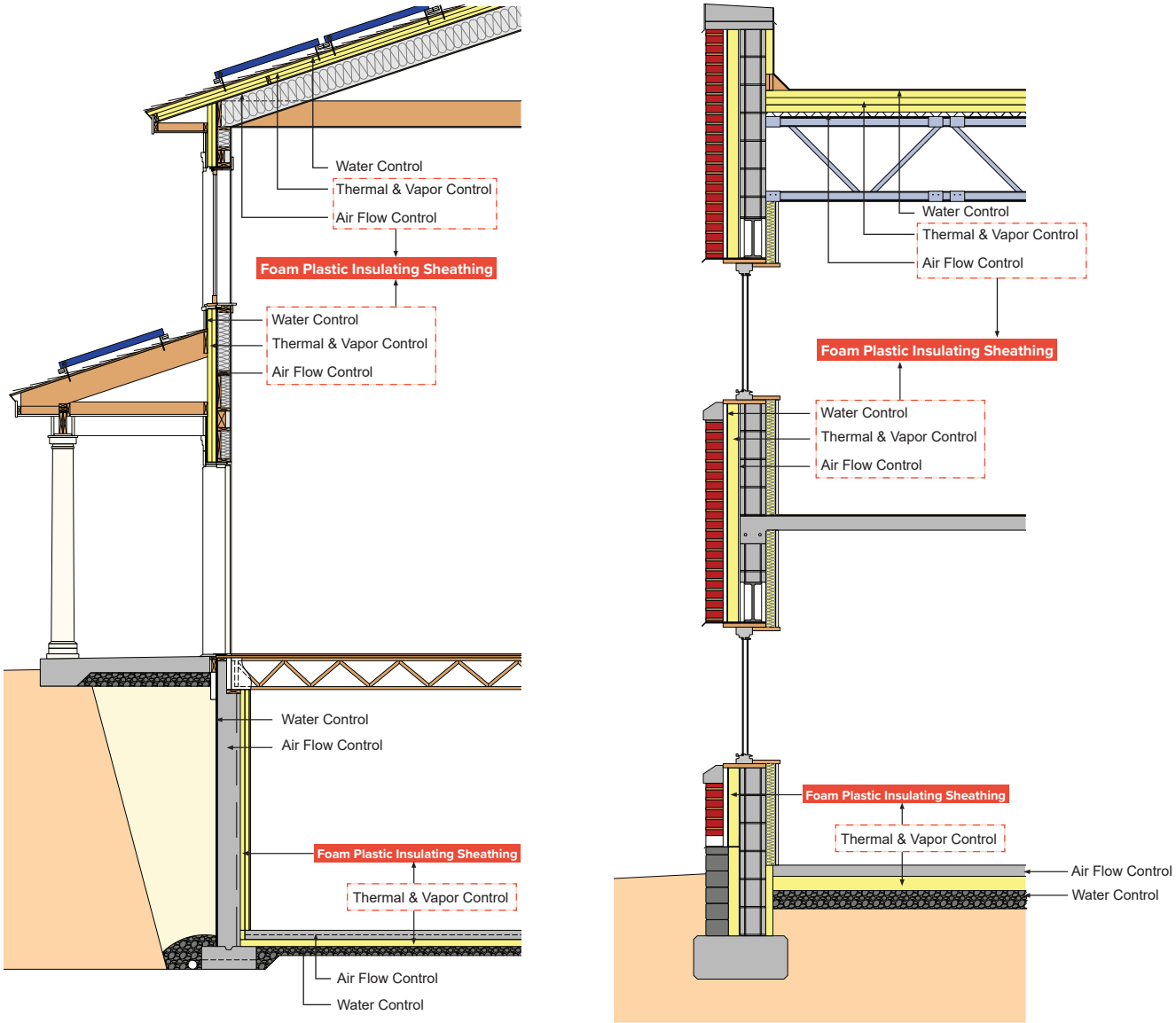

Figure 1. FPIS ci multifunctional applications provide continuity of building enclosure control layers for passive house performance.

What are typical Passive House insulation requirements?

The insulation requirements for passive house construction are driven by a building envelope performance metric known as Thermal Energy Demand Intensity (TEDI). TEDI is a measure of a building's heating load on a per-unit-area basis of an overall building (e.g., kBtu/ft^2/yr or kWh/m^2/hr). A separate TEDI metric may also be applied to cooling loads.

This "load" or heating/cooling energy demand is directly associated with the performance of the building thermal envelope. A higher TEDI means greater heating/cooling energy demand whereas a lower TEDI means less energy use (and smaller HVAC equipment). In general, the TEDI performance levels set for passive house compliance require high performance (i.e., highly insulated) building envelope assemblies. However, it does not prescribe the insulation level for any particular assembly or climate zone. The TEDI limit, which only addresses thermal performance, may be satisfied in a variety of ways, but using a multifunctional application of FPIS ci can result in overall optimization of a passive-house-compliant building enclosure.

Typical passive house R-values for building insulation may be roughly characterized as follows without important distinctions regarding insulation material or method:

- **Walls:** R-35 or greater
- **Roof/Attic:** R-60 or greater
- **Foundation:** R-30 or greater

The U-factor is a more accurate, meaningful, and flexible way to characterize insulation requirements because it properly accounts for heat transmission through a full assembly and properly distinguishes the value of continuous insulation (not thermally bridged) and cavity insulation (thermally bridged by structural framing and components). A typical U-factor for passive building thermal envelope assemblies ranges from 0.018 to 0.026 Btu/hr-ft^2-F (0.10 to 0.15 W/m^2-K). For a very limited example, this range of U-factors may result in the following two representative R-value solutions for a typical 2x6 wood frame wall:

- **Example 1:** R21batt + R20ci (U-0.026)
- **Example 2:** R15batt + R14ccSPF + R30ci (U-0.018)

Example 1 uses standard batt insulation in the cavity and an R20ci. This wall can be constructed with a total thickness of 3-5" of FPIS ci on the exterior side of a 2x6 wall, whereas other forms of continuous insulation may require up to 6" of exterior insulation. (**NOTE:** See Figure 2 which is a wall detail consistent with Example 1 and used on an actual net zero home with passive-house insulation levels.)

Example 2 uses about 2" of closed cell spray polyurethane foam insulation with an R15 fiberglass batt (i.e., flash and batt) in the wall cavity between 2x6 studs together with R30ci to achieve a super-insulated wall assembly with a significantly lower U-factor. FPIS ci

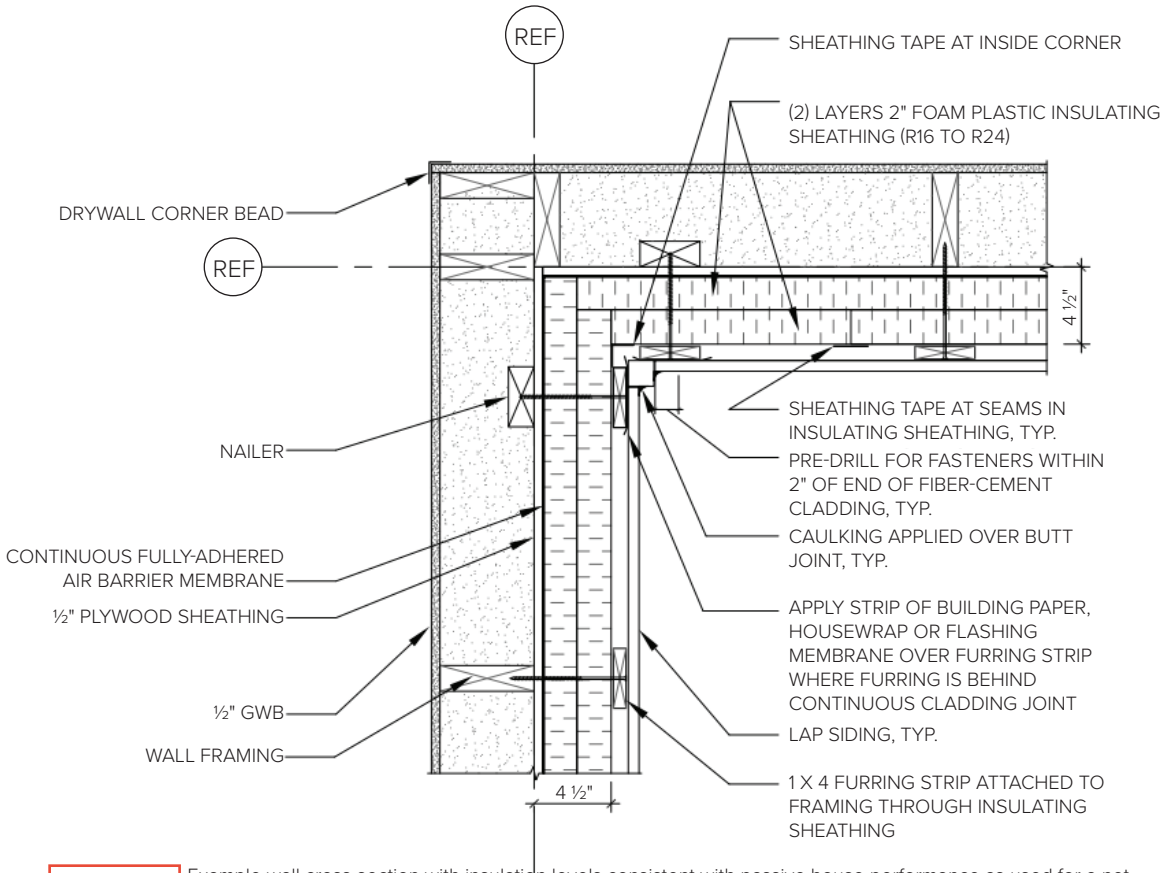

Figure 2. Example wall cross-section with insulation levels consistent with passive house performance as used for a net zero energy home. (Source: https://www.nist.gov/el/net-zero-energy-residential-test-facility/project-details)

achieves this much greater R30ci insulation level with much less overall thickness of the wall assembly and with less difficulty in cladding attachment/support, window attachment/support, and flashing. (**NOTE:** Example 2 may be more appropriate for extremely cold climates.)

Both examples above would perform well from a thermal and moisture control standpoint in all climate zones when paired with an appropriate interior vapor retarder to allow for balanced inward drying. In general, it is good practice (and actually a code requirement for above deck roof insulation) to install FPIS ci in at least two layers with joints staggered. Plus, when FPIS ci is also used as the air barrier and water-resistive barrier, only one of the layers would require the joints to be sealed. Consequently, that same layer must also be made continuous with the water-resistance plane and air-barrier plane of adjoining building assemblies and components.

■ Where can I find more information about Passive House construction?

United States (Domestic)

- Passive House Institute US (PHIUS)
- Passive Building Design Guide (by PHIUS)
- Climate-Specific Passive Building Standards (Building America Program, U.S. Department of Energy)
- 2025 Massachusetts Building Energy Codes (Stretch Code)
- Cold Climate Housing Research Center: REMOTE Walls

International

- Passive House Institute (PHI) (Germany)
- International Passive House Association (IPHA)
- The Passivhaus Trust (United Kingdom)

Other Articles of Interest

- BSD-025: The Passive House (Passivhaus) Standard — A comparison to other cold climate low-energy houses
- How Much Insulation Do You Need in a Passive House?

Credit: D. Poppendieck/NIST