Energy Design Update
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IN PRACTICE

Building the Future: A Builder's Personal Dream Home Hits HERS 35 (Part 1)

Winner of the 2013 "Lowest HERS Index without Renewable Technologies" in the CT Zero Energy Challenge, the Trolle Residence in Danbury, Connecticut is the noteworthy culmination of a builder's dream for his own personal residence (see Figure 12).

Trolle first got involved in green building in 1998, and by 2000 Trolle's BPC Green Builders, LLC built the first home in Connecticut certified as an American Lung Association® Health House RX™, verified by the Conservation Services Group of Westboro, Massachusetts. BPC and Trolle went on to earn multiple Silver, Gold, and Platinum Leadership in Energy and Environmental Design (LEED)® for Homes certifications, a National Green Building Standard™ (NGBS) Emerald certification, as well as to win "Best Energy Efficient & Green Home" in Connecticut for 2004 and 2006 (HOBI Awards), "Best Green Renovation" in Connecticut for 2011 (Home Builders Association of CT), and "Best Use of Advanced Building Technology" Green Home of the Year Awards program (*Green Builder* magazine).

Given this track record of extraordinary performance, for his own home, Trolle wanted the most efficient house possible. Earning a final Home Energy Rating System (HERS) Index of 35, the Trolle Residence is also a certified Passive House through the Passive House Institute US (PHIUS), an ENERGY STAR® Certified Home, a certified Zero Energy Ready Home through the Department of Energy's Building America program, and is certified under the US Environmental Protection Agency's (EPA) Indoor airPLUS program. Notably, Trolle's home earned a HERS 35 without the use of renewables (see Sidebar 1).

Trolle's envelope insulation strategy was comprehensive and continuous.

"For the best in home performance and efficiency, you want high levels of insulation, for a high percentage of that insu-

Figure 12. Finished exterior of the Trolle Residence. The home garnered an impressive final Home Energy Rating System (HERS) Index of 35, without renewables. Photo courtesy Mike Trolle.

Figure 13. Shallow frost-protected foundation during assembly. Photo courtesy Mike Trolle.

lation to be continuous, and for the home to be air-tight," Trolle stressed.

After re-purposing the existing concrete block foundation, Trolle began at ground level and chose a frost-protected shallow foundation (refer to Figure 13). Trolle laid out the recipe he used: an initial 6" layer of crushed stone, followed by a 12" layer of expanded polystyrene (EPS) rigid foam insulation, with short blocks of 6" EPS around the perimeter forming a shallow basin that was then filled with concrete. "The EPS isolates the concrete from the ground and the outside air, which prevents thermal bridging," Trolle noted. (Refer to Figure 14 for a detailed section of the home.)

The home's walls were framed with 2'×6' studs to create 5 1/2" cavities for insulation. Studs are spaced 24" apart, instead of the normal 16", allowing for more insulation and less wood in the wall assembly. Engineered trusses, structural wood assemblies manufactured off-site, were used for the roof. Trolle selected the trusses to avoid heat transfer and to accommodate an eventual 18" of cellulose insulation – about R-65. Raised heel trusses were used in the attic framing to al-

Sidebar 1.

Size: 1,650sf, 3 bedrooms

Certification Programs:

- PHIUS, Passive House Institute US
- EPA, ENERGY STAR Certified Homes (HERS Index 35, no renewables)
- Zero Energy Ready Homes, DOE, Building America Partner
- EPA, Indoor air PLUS

Building Site

- Tapered lot on a hill in a lake community
- Existing residence was dismantled and new home built on existing foundation
- There is no natural gas available on site; fuel sources changed from oil to electric and propane

House Envelope

- 12" expanded polystyrene (EPS) foam board (R-58) under new frost-protected shallow slab foundation, and 6" EPS (R29) applied to exterior of the shallow slab walls.
- 2x6 wall construction with 5-1/2" of blown cellulose (R20), plus two layers, 5-1/2" of polyisocyanurate foam board (R37).
- Further to the reduction of thermal bridging, there are two stud corners, insulated headers, and interior wall to exterior wall intersections left open to receive insulation.
- To reduce air infiltration all sheathing joints are taped as are rough openings around doors and windows. The entire outer envelope of the house has been sheathed with plywood with taped joints.
- Windows and exterior doors feature PVC frames and triple glazing with argon gas fill and two low-E coatings with U-value of 0.12. Skylights are clad wood with similar glazing and U-value of 0.14.
- Blown cellulose fills the 18" open-web roof trusses (R68).
- 2" of 2lb SPF plus 5.5" of ½" SPF (R34) insulates the 2x8 floor joists over the existing unconditioned basement, with 2.5" of mineral wool boards (R10) underneath the joists.

HVAC Systems

- The majority of the heating load is satisfied by internal and solar heat gains. The south wall of the house has 95sf of glazing with a 0.61SHGC that admits solar heat during the cold months that will be absorbed by the heavily insulated shallow slab foundation.
- The house is heated and cooled by a one-ton, air-source heat pump. A ducted fan moves conditioned air around the house from the Great Room where the heat pump is located.
- Ventilation is provided by an energy recovery ventilator (ERV) which draws exhaust air from the bathrooms and kitchen (and ventilates them) while simultaneously providing fresh air to the entire house.
- A high efficiency, condensing, tankless, propane-fired hot water heater creates hot water for domestic use.

Plumbing & Electrical

- The hot water piping is insulated with R-3 insulation.
- Low-flow faucets and toilets are used throughout the home to conserve water.
- The refrigerator, dishwasher, & clothes washer are all Energy Star rated. The dryer is a condensing unit that does not require an exterior vent.
- Daylight will be the primary source of light. The electric lighting will be a mixture of fluorescent and LED fixtures; standard fixtures will have CFL or LED bulbs.

Additional "Green" Features in the Home

- Low VOC sealants, caulks, adhesives, primers, and paints
- Existing bluestone from the original house and natural stone from the excavation work has been used for walls and walkways
- Roof overhang shades the south wall from Summer sun
- Re-used w/w carpeting
- Re-used concrete block foundation
- Re-used some paneling
- Accommodations for future PV arrays on roof
- Green demolition: full abatement of asbestos, lead; off-site separation of clean debris

low for insulation over the outside walls, preventing ice dams. All spaces between the top and bottom wood members of the trusses were filled with insulation to reduce thermal bridging. The attic space, deemed too small for storage, was filled with 24" of blown-in cellulose, rating up to R-86.

"The exterior walls of my house feature three layers of insulation," Trolle noted. Layer 1 is blown cellulose filled between the 2'x6' studs. This initial layer earns the walls an insulation value of R-20. On the exterior, Trolle taped plywood sheathing joints to make the walls airtight. Next, 2" of polyisocyanurate (polyiso) were installed between 2'x3's (over ripped strips of ½" CDX) that run horizontally and are bolted to the wall studs. Layer 3 is 3 1/2" of polyiso installed continuously over the first. Trolle devised the two-layered polyiso strategy to eliminate any thermal bridging from the framing.

To attach the exterior cement board siding to the wall, the siding was nailed to 1'x3' wood strips. Strips were bolted through the top layer of polyiso insulation. Beneath the siding, a 3/4" drainage plane was incorporated. Overall, exterior walls at the Trolle Residence earned an R-value of 55.

Why build a wall that is insulated to an R-value three times the building code minimum? Trolle laid out the answer in a blog for BPC: "Well, it cost my family only $200 worth of electricity to heat the 1,650 square foot house this winter, with the interior temperature at 70°, day and night. A high level of comfort was assured because the interior surface temperature of the floors, walls and roof was the same as the room air temperature, and air leakage was non-existent. It's a night and day comparison to conventional code-based construction."

Lots of flashing tape helped bring air tightness to 0.46 ACH50.

For Passive House certification, a home must meet an airtightness level of 0.6 ACH50 or less. Getting leaks sealed and avoiding penetrations in the envelope are paramount (see Figure 15).

Trolle used both Pro Clima TESCON VANA, a European flashing tape, and 3M™ All Weather flashing tape on the project. All intersections of floor, wall, and roof planes were taped, and flashing tape was also applied at each installation of windows and doors. Additionally, BPC attached 1/2" plywood to the interior underside of each roof truss and taped the joints. Where interior ceiling plywood met exterior plywood sheathing on walls, "Wider flashing tape was used to seal this critical joint," Trolle highlighted.

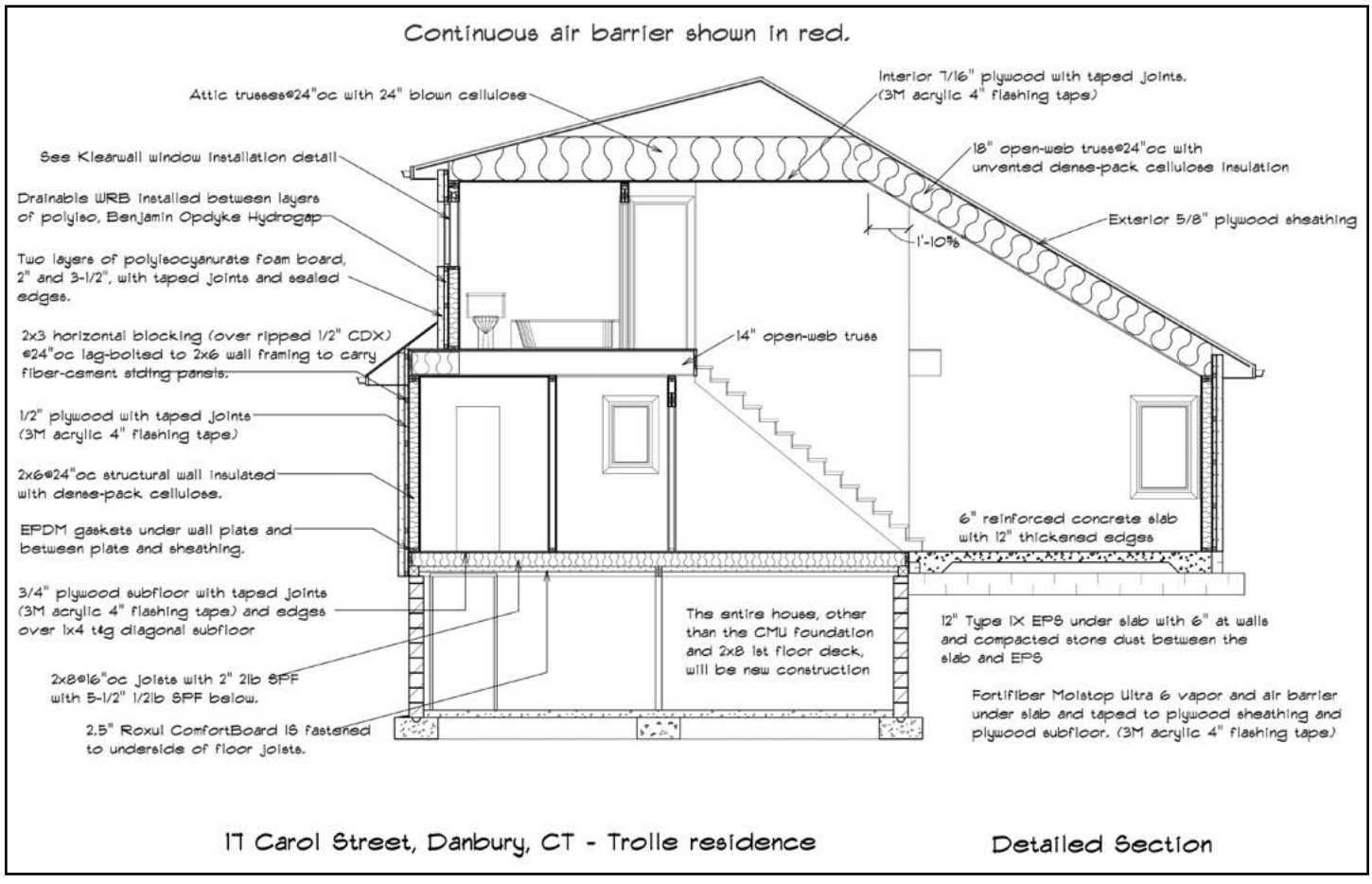

Figure 14. Detailed section of the Trolle Residence. Figure courtesy Mike Trolle.

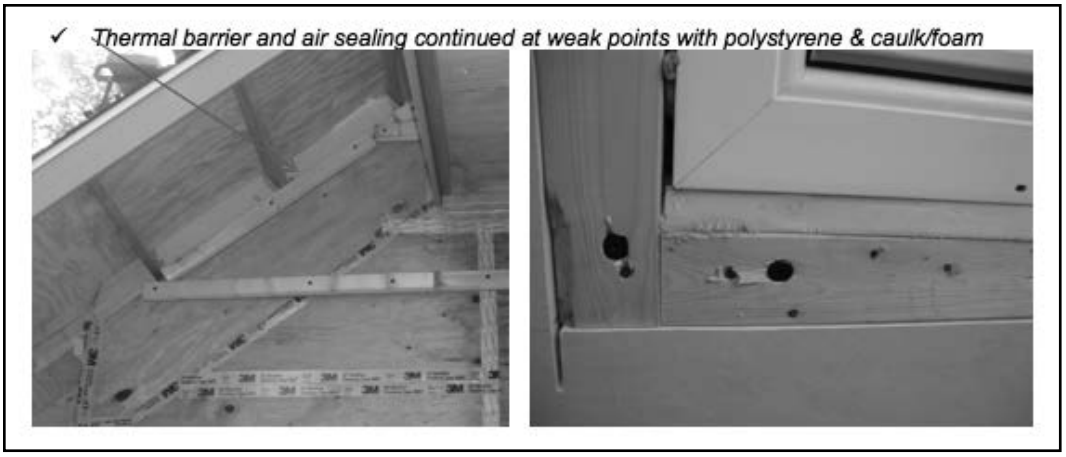

Figure 15. Confirmation photos of thermal and air sealing at weak points in the envelope. Photos taken during intermediate inspection by Steven Winter Associates, Inc. Photos courtesy Mike Trolle.

Ultimately, a third-party blower door test showed 0.46 ACH50 for the home, which easily meets the PHIUS certification standard. "The current code requirement in Connecticut is 7.0 ACH50, nearly twelve times the Passive House standard," said Trolle. "This is yet another instance where the code standard for this critical efficiency element is well behind the times."

In the second installment of this article, ***Energy Design Update*** will explore the Trolle Residence mechanical systems and lessons learned.

Energy Design Update sincerely thanks Mike Trolle, BPC Green Builders, LLC, Robb Aldrich, and Steven Winter Associates, Inc, for sharing this story with us. BPC Green Builders can be visited online at *http://www.bpcgreenbuilders.com/*. To learn more about the CT Zero Energy Challenge, go to *https://www.ctzeroenergychallenge.com/*.

Information about Passive House Institute US (PHIUS) certification is available online at *http://www.passivehouse.us/passiveHouse/PHIUSHome.html*. Information about the Zero Energy Ready Home certification, formerly the Challenge Home, from the Department of Energy's Building America program, is online at *http://energy.gov/eere/buildings/zero-energy-ready-home*.

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