U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE ZERO ENERGY READY HOME™

Housing Innovation Awards

BPC Green Builders

Trolle Residence
Danbury, CT

BUILDER PROFILE

BPC Green Builders, Wilton, CT
Mike Trolle, 203-563-9909
www.bpcgreenbuilders.com
Rater: Steven Winter Associates, Karla Donnelly
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FEATURED HOME/DEVELOPMENT:

Project Data:

- Name of Project: Trolle Residence
- Location: Danbury, CT
- Layout: 3 bedrooms, 2.5 baths, 2 floors
- Conditioned Space: 1,680 ft^2
- Completion: November 2013
- Cimate Zone: IECC 5A, cold
- Category: Custom

Modeled Performance Data:

- HERS Index: without PV 35
- Builder's Added Cost Over 2009 IECC: $0
- Projected Total Annual Energy Cost Savings: without PV $1,008
- Projected Annual Utility Costs: without PV $1,642
- Annual PV production revenue: NA
- Annual Energy Savings: without PV 6,276 kWh

"Snow is cold, rain is wet, Chills my soul right to the marrow I won't be happy … Till I'm home again and feeling right."

Carole King penned these lyrics long before the 1950s bungalow on the street named after her in Danbury, Connecticut, was rebuilt as an ultra-energy-efficient home, but the words sum up how the homeowners feel about their new home, a lake-front cottage that has received a Zero Energy Ready Home certification from the U.S. Department of Energy's Building America program.

"It is pretty amazing when you are sitting in this house in the middle of winter and it's zero degrees outside and 70 degrees inside with almost no temperature difference from room to room and your only heat source is a little box hanging on the outside wall" said homeowner and custom home builder Mike Trolle. The home's single mini-split heat pump effectively heats and cools the entire two-story 1,650-ft^2 home, thanks to a highly insulated and airtight building shell that meets Passive House standards.

"We've been in the house since November of 2013, and we have yet to spend more than $60 in a month on heating. It's been roughly $200 for the entire heating season," said Trolle.

Trolle is used to building 10,000-ft^2 custom homes, but he bought the property on Carol Street in 2012 with the goal of building a home that would outperform anything he had built before and be cost-effective enough for the average family to afford. The existing structure was one of 240 summer cottages built around a lake in west Connecticut by a group of firefighters from Brooklyn, including one who was Carole King's father. While most of the cottages have been turned into year-round homes, none have gotten the complete overhaul of the Trolle home.

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

The U.S. Department of Energy invites home builders across the country to meet the extraordinary levels of excellence and quality specified in DOE's Zero Energy Ready Home program (formerly known as Challenge Home). Every DOE Zero Energy Ready Home starts with ENERGY STAR Certified Homes Version 3.0 for an energy-efficient home built on a solid foundation of building science research. Advanced technologies are designed in to give you superior construction, durability, and comfort; healthy indoor air; high-performance HVAC, lighting, and appliances; and solar-ready components for low or no utility bills in a quality home that will last for generations to come.

Two layers of polyisocyanurate cover the home's exterior. The first layer, 2-in. glass-fiber-faced foam board, was mounted in horizontal panels separated by 2x3s. The second layer, 3.5 in. foil-faced foam, was secured with furring strips lag bolted into the 2x3s, which are bolted into the 2x6 wall studs. An additional R-20 of dense-packed cellulose fills the wall cavities for a super-insulated shell.

What makes a home a DOE ZERO ENERGY READY HOME?

1 **BASELINE**
ENERGY STAR Certified Homes Version 3.0

2 **ENVELOPE**
meets or exceeds 2012 IECC levels

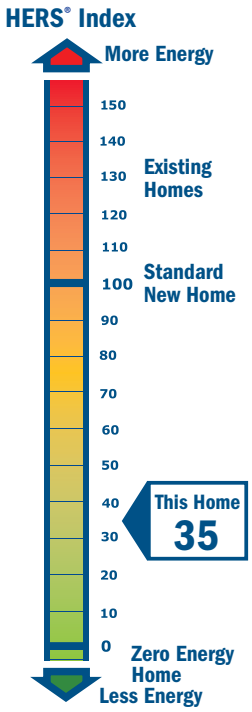
3 **DUCT SYSTEM**
located within the home's thermal boundary

4 **WATER EFFICIENCY**
meets or exceeds the EPA WaterSense Section 3.3 specs

5 **LIGHTING AND APPLIANCES**
ENERGY STAR qualified

6 **INDOOR AIR QUALITY**
meets or exceeds the EPA Indoor airPLUS Verification Checklist

7 **RENEWABLE READY**
meets EPA Renewable Energy-Ready Home.



Trolle tore the old cottage down to the foundation, a 24x26 ft basement with concrete walls that are 4-ft tall on the south side and 8-ft tall on the north side. Rather than insulating this existing basement, which was built into the hillside and has a floor that varies in height, he air-sealed and insulated the new ceiling above the basement. The underside of the 2x8-framed floor was sprayed with 2 inches of closed-cell spray foam plus 5.5 inches of open-cell spray foam (for a combined insulation value of R-32) to fill the floor joist cavities, then 2.5 inches of mineral wool board was screwed to the bottom of the joists to provide an additional R-11 and to stop any thermal bridging through the joists from the uninsulated basement to the insulated space above. To maintain the air sealing and thermal boundary between the basement and the house, there are no stairs from the main floor into the basement and no other holes through the foundation to the conditioned living area above. The basement, which is only used for storage, is accessed from outside. The "rat slab" concrete floor and existing foundation walls were covered with 7-mil polyethylene with overlapping sealed seams. The energy raters for the home, Steven Winter Associates, documented this unconventional assembly, allowing the home to meet EPA Indoor airPLUS and ENERGY STAR Certified Homes Version 3.0 requirements.

On the uphill side of the existing foundation, Trolle leveled an additional 600 ft^2 of ground, put down crushed stone, and then laid 12-inch-thick 4x8-ft sheets of rigid expanded polystyrene (EPS) to form an insulated base giving the home a final foot print of 27x38 ft, plus an 8x18 side room. Six-inch-thick pieces of EPS rigid foam were inserted into slots cut into the perimeter to form the slab edge insulation. The foam layer was covered with a fiber-reinforced 6-mil polyethylene vapor barrier, then a 6-inch concrete slab was poured. Although code typically requires footings to be set 42 inches below grade in Connecticut to be below the frost depth, insulating under the entire slab and footing was an acceptable alternative that saved Trolle in excavation costs.

The 2x6 framed walls were filled with 5.5 inches of dense-packed cellulose having an R-20 insulation value. Over the plywood sheathing, Trolle installed two layers of polyisocyanurate foam board. The first layer was a 2-inch-thick polyiso foam board with a glass mesh facing that was installed between 2x3's (plus half-inch strips of plywood) placed horizontally on the wall at 24 inches on center and attached to 2x6 studs with lag bolts. A drainage-type house wrap was installed horizontally over this layer. The next layer was a 3.5-inch-thick polyiso foam board with a foil facing that was held in place with 1x3 furring strips, installed

Wood subfloor covers the existing basement. A 12-inch layer of EPS rigid foam covers the remainder of the floor area, which has been prepared for pouring of the concrete slab. In the white section to the left, leftover pieces were stacked on for an additional 6 inches of foam while rock dust covers the foam in the section to the right. The 6-inch-thick perimeter slab edge insulation is covered with vapor barrier in this photo.

vertically, that were attached through the foam to the 2x3's with lag bolts. The total wall R-value of R-55 greatly exceeds the insulation requirements of the 2009 and 2012 International Energy Conservation Codes (IECC).

The vented attic has 24 inches (R-86) of blown cellulose sitting on the ceiling deck. The attic was constructed with raised heel trusses to accommodate 12 inches of insulation over the exterior wall sill plates. The unvented vaulted ceiling to the rear has 18 inches (R-68) of dense-pack cellulose installed between open-web trusses. In the attic and vaulted ceilings, plywood was attached to the interior of the roof trusses and then taped at the seams and connecting joints to the exterior plywood sheathing to maintain the envelope's air-tightness.

Additional air sealing measures included taping the joints of a new subfloor over the existing framed deck above the basement, taping the polyethylene under the slab to the subfloor and to the exterior wall sheathing, and taping the window and door openings. This level of airtightness ensures there are no air leaks letting out conditioned air and compromising energy-efficiency. A tightly sealed home also keeps out pests, dust, and soil gases. However, for good indoor air quality some fresh air needs to be brought into the house, and the best way to do this is with a controlled ventilation system. Trolle chose to install an energy recovery ventilator (ERV) with ducts that supply fresh air to the open living area while pulling stale air from the kitchen and the bathrooms. The ERV runs continuously to meet the ASHRAE 62.2 residential ventilation requirement.

Fresh air is provided to the great room near the home's only heating and cooling source, a wall-mounted one-ton ductless heat pump. Trolle noted that, at one ton, the heat pump is actually oversized for the home, which has a winter heating load of about 7.0 kBtus. A typical code-built 1,650 ft^2 home would have a winter heating load of about 22.0 kBtus. The air source heat pump has a heating season performance factor (HSPF) of 10.5 and a seasonal energy efficiency rating (SEER) of 23 (above the standard of 7.6 HSPF, 13 SEER). It is equipped with variable refrigerant flow technology, allowing it to adjust to the demands of the current temperature conditions. The ductless heat pump blows air directly into the room where it is located. However, Mike Trolle and his brother Chris Trolle, a mechanical engineer, designed a system that uses an in-line fan located in a duct that passes between the first and second floors to push conditioned air between floors. The ERV's supply and exhaust ducts also contribute to air mixing.

HOME CERTIFICATIONS

DOE Zero Energy Ready Home Program, 100% commitment

ENERGY STAR Certified Homes Version 3.0

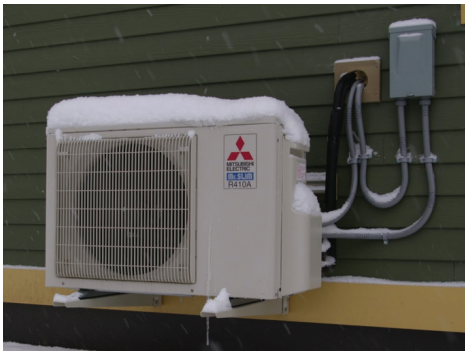
EPA Indoor airPLUS

EPA WaterSense

Passive House Institute U.S. Standard (PHIUS+)

2013 CT Zero Energy Challenge Winner, lowest HERS without PV

Every DOE Zero Energy Ready Home combines a building science baseline specified by ENERGY STAR Certified Homes with advanced technologies and practices from DOE's Building America research program.



A single one-ton mini-split ductless heat pump (outdoor unit shown here) was enough to heat and cool the entire 1,650 ft² two-story home. A small duct with an inline fan helped pull conditioned air through the ceiling to upstairs bedrooms. An ERV provided fresh air ventilation and also helped to circulate conditioned air with a supply duct in the great room and return ducts in the bedrooms and bathrooms.

Mike Trolle explained that the low heating and cooling load is a goal of Passive House construction. "You build a thermal envelope that is highly insulating to get the load down. Then the house will get half of its heating from the sun and one-fourth from internal gains [people, lighting, electronics], leaving only one-fourth of the load to cover—and even that is drastically reduced from typical construction."

The majority of the heating load in the Trolle home is satisfied by internal and solar heat gains. The south wall of the house has 95 ft² of window glazing with a 0.61 solar heat gain coefficient (SHGC). This heat is absorbed by the heavily insulated concrete slab foundation during daylight hours and radiated back into the room space at night. In the summer, most of this solar gain is blocked by deciduous trees and a deep roof overhang.

Hot water is provided to the home with a tankless propane water heater with an energy factor of 0.97. The water heater is located in the same corner of the house as the kitchen, laundry, and bathrooms to meet the DOE Zero Energy Ready Home's stringent hot water distribution limits.

Trolle felt that meeting the requirements of the DOE Zero Energy Ready Home program ultimately did not increase the cost over constructing a home to the current state building code, which in Connecticut is the 2009 IECC. "The cost increased due to the additional insulation and air sealing, but it decreased because we were able to install a much smaller and simpler HVAC system."

Trolle appreciates what he's learned about DOE's Zero Energy Ready Home program in the process. "We are working on three homes right now that are being built to the DOE Zero Energy Ready Home standard. I plan to make DOE Zero Energy Ready the standard that I'll offer for our customers. Not everyone wants to go to Passive House levels. DOE Zero Energy Ready Home is a very sensible upgrade from the current building code for a modest price premium that homeowners will get back in a short amount of time. I don't think we will build to anything less."

Trolle has shared the knowledge he's gained with local builders. The home was part of a 2013 tour for the Connecticut Green Building Council Green Homes Committee and the 2013 Northeast Sustainable Energy Association Green Open House.

Photos courtesy of BPC Green Builders.

KEY FEATURES

- **DOE Zero Energy Ready Home Path**: Performance
- **Walls:** 2x6 wall with R-20 dense-packed cellulose; one 2-in. layer and one 3.5-in. layer (R-35) of rigid polyiso over plywood sheathing; drainage house wrap between polyiso layers; all layers taped at seams
- **Roof:** Asphalt roof shingles
- **Attic:** R-86 cellulose (24 in.) on flat ceiling; R-68 dense packed in vaulted ceiling
- **Foundation:** Slab on grade, R-28 rigid foam at perimeter to 18 in. below grade. R-55 rigid EPS under new slab. Floor above existing basement insulated with 2.5 in. closed-cell spray foam and 5.5 in. open-cell spray foam for R-32 in floor joist cavity plus 2.5 in. (R-11) mineral wool rigid foam beneath joists
- **Windows:** Triple-pane, low-e windows with U=0.14 and SHGC=0.49 (south side SHGC=0.61; skylight SHGC=0.20)
- **Air Sealing:** 0.45 ACH 50
- **Ventilation:** ERV runs continuously to meet ASHRAE 62.2
- **HVAC:** Ductless heat pump; 1-ton unit, HSPF 10.5, SEER 23; one duct with in-line fan to move air from great room to upstairs and rear bedrooms
- **Hot Water:** Instant propane water heater, EF 0.97; R-3 piping insulation
- **Lighting:** 42% LED; 58% CFL
- **Appliances:** ENERGY STAR refrigerator, clothes washer, and dishwasher; unvented condensing-type clothes dryer
- **Solar:** None installed; solar ready conduit
- **Water Conservation Features:** All WaterSense fixtures
- **Other:** Low- and no-VOC materials; passive solar design; reuse of concrete, stone, doors, and wood from original house

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